

Industrial Boiler Combustion Modification
NOx Controls. Volume II: Stoker-Coal-Fired
Boiler Field Test - Site A

Acurex Corp.
Mountain View, CA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Jul 81



U.S. Department of Commerce
National Technical Information Service

NTIS



United States
Environmental Protection
Agency

EPA-600/7-81-126b

July 1981

P B82-231085

Research and Development

INDUSTRIAL BOILER COMBUSTION
MODIFICATION NO_x CONTROLS
Volume II. Stoker-coal-fired Boiler
Field Test--Site A

Prepared for

Office of Air Quality Planning and Standards

Prepared by

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA-600/7-81-126b	2.	3. RECIPIENT'S ACCESSION NO. PB82-231085
4. TITLE AND SUBTITLE Industrial Boiler Combustion Modification NOx Controls: Volume II. Stoker-Coal-Fired Boiler Field Test--Site A	5. REPORT DATE July 1981	
7. AUTHOR(S) P. M. Goldberg and E. B. Higginbotham		6. PERFORMING ORGANIZATION CODE
9. PERFORMING ORGANIZATION NAME AND ADDRESS Acurex/Energy and Environmental Division 485 Clyde Avenue Mountain View, California 94042		8. PERFORMING ORGANIZATION REPORT NO.
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO. EHE624A
		11. CONTRACT/GRANT NO. 68-02-2160 and 68-02-3176, Task 12
		13. TYPE OF REPORT AND PERIOD COVERED Task Final; 7/78-7/79
		14. SPONSORING AGENCY CODE EPA/600/13
15. SUPPLEMENTARY NOTES IERL-RTP project officer is Joshua S. Bowen, Mail Drop 65, 919/541-2470.		
16. ABSTRACT The report gives methods and results of an environmental assessment test program at an industrial site. The aim of the program was to measure multimedia emissions changes as a result of applying NOx controls. Emissions of trace elements, organic materials, sulfur species, SO2, NOx, CO, and particulate matter were measured. These emissions, under normal and controlled (for NOx) operating conditions, were compared. Source operating data were also analyzed so that changes in operating parameters and efficiency could be assessed. This unit is a spreader-stoker coal-fired boiler rated at 38 kg/s (300,000 lb/hr) of steam. The fuel tested was low-sulfur coal. High overfire air firing (constant overall air flow) was used for NOx control. These measures reduced NOx by about 10% from baseline. Increased overfire air levels also improved boiler efficiency. These tests lasted about 5 hours; long-term operation under test conditions was not addressed in this program. Test results suggest that applying combustion modification NOx controls increased particulate and organic emissions. <		
17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Boilers Combustion Control Nitrogen Oxides Stokers Coal	Pollution Control Stationary Sources Industrial Boilers Combustion Modification Stoker Coal	13B 13A 21B 07B 21D
18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified 20. SECURITY CLASS (This page) Unclassified	21. NO. OF PAGES 182 22. PRICE

ATTENTION

AS NOTED IN THE NTIS ANNOUNCEMENT,
PORTIONS OF THIS REPORT ARE NOT LEGIBLE.
HOWEVER, IT IS THE BEST REPRODUCTION
AVAILABLE FROM THE COPY SENT TO NTIS.

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the INTERAGENCY ENERGY-ENVIRONMENT RESEARCH AND DEVELOPMENT series. Reports in this series result from the effort funded under the 17-agency Federal Energy/Environment Research and Development Program. These studies relate to EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy systems. The goal of the Program is to assure the rapid development of domestic energy supplies in an environmentally-compatible manner by providing the necessary environmental data and control technology. Investigations include analyses of the transport of energy-related pollutants and their health and ecological effects; assessments of, and development of, control technologies for energy systems; and integrated assessments of a wide range of energy-related environmental issues.

EPA REVIEW NOTICE

This report has been reviewed by the participating Federal Agencies, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EPA 600/7-81-126b
July 1981

INDUSTRIAL BOILER COMBUSTION MODIFICATION NO_x CONTROL
VOLUME II: STOKER COAL-FIRED BOILER FIELD TEST
SITE A

by

P. M. Goldberg and E. B. Higginbotham

Acurex Corporation
Energy & Environmental Division
485 Clyde Avenue
Mountain View, California 94042

Contract No. 68-02-2160

Project Officer

J. S. Bowen
Combustion Research Branch
Energy Assessment and Control Division
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina 27711

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

ABSTRACT

This test report describes the methods and results of an environmental assessment test program conducted at an industrial site. The purpose of the test program was to measure changes in multimedia emissions as a result of applying NO_x controls. Emissions of trace elements, organic materials, sulfur species, and the criteria pollutants, SO₂, NO_x, CO and particulate matter, were measured. Comparisons of these emissions under normal operating conditions and controlled (for NO_x) operating conditions were then made. Source operating data were also analyzed so that changes in operating parameters and efficiency could be assessed.

This unit is a spreader stoker coal-fired boiler rated at 38 Kg/s of steam (300,000 pounds steam per hour). The fuel tested was a low sulfur coal.

High overfire air firing (constant overall air flow) was used for NO_x control. These measures achieved NO_x reductions from baseline levels of about 10 percent. Increased overfire air levels also gave an improved boiler efficiency. These tests were about 5-hours in duration. Continuous operation under the test conditions was not addressed in this program.

Some changes in trace element partitioning and emissions were measured with the application of NO_x controls. Changes in organic emissions also were measured when NO_x controls were applied.

CONTENTS

<u>Section</u>		<u>Page</u>
	Abstract	ii
	Figures	iv
	Tables	v
	Acknowledgment	vii
1	INTRODUCTION	1-1
2	TEST SITE DESCRIPTION	2-1
3	TEST PLAN	3-1
	3.1 Unit Operation	3-1
	3.2 Sampling and Analysis	3-3
	3.2.1 Sampling	3-3
	3.2.2 Analysis	3-7
4	TEST PROGRAM RESULTS	4-1
	4.1 Unit Operation	4-1
	4.2 Flue Gas Composition	4-3
	4.3 Particulate Emissions	4-5
	4.4 Operating Efficiency	4-12
	4.5 Trace Element Characterization and Emissions	4-14
	4.6 Sulfur Species Emissions	4-27
	4.7 Organic Analyses	4-29
	4.7.1 Total Chromatographable Organics (TCO) and Gravimetric Analyses of Organic Extracts	4-29
	4.7.2 Infrared Spectra of Total Sample Extracts	4-32
	4.7.3 Column Chromatography	4-35
	4.7.4 C ₁ to C ₆ Flue Gas Hydrocarbon Analysis	4-35
	4.7.5 Summary of Organic Analysis	4-38
5	SUMMARY	5-1
	REFERENCES	R-1
	APPENDICES	
A	OPERATING DATA AND EFFICIENCY TEST RESULTS	A-1
B	ANALYTICAL PROCEDURES	B-1
C	TRACE ELEMENT CONCENTRATIONS	C-1
D-1	TRACE ELEMENT FLOWRATES (kilograms per minute)	D-1
D-2	TRACE ELEMENT FLOWRATES (micrograms/joules)	D-2
D-3	TRACE ELEMENT FLOWRATES (micrograms per dry standard cubic meter)	D-3
E	ORGANIC ANALYSIS DATA	E-1

FIGURES

<u>Figure</u>		<u>Page</u>
2-1	Boiler System Diagram	2-2
3-1	Sampling Locations	3-4
3-2	Source Assessment Sampling System (SASS) Schematic (Reference 5)	3-8
4-1	SASS Particulate Size Distribution	4-8
4-2	System Ash Flows	4-13

TABLES

<u>Table</u>		<u>Page</u>
1-1	NO _x EA Field Test Program	1-2
3-1	Boiler Operating Conditions	3-2
3-2	Continuous Monitors Used in Testing	3-6
3-3	Sample Analysis	3-9
4-1	Coal Analysis (Percent by Weight)	4-2
4-2	Flue Gas Composition	4-4
4-3	Method 5 Particulate Concentrations	4-6
4-4	SASS Particulate Concentrations	4-6
4-5	SASS Particulate Sizing (Cumulative Weight Percent Oversize)	4-9
4-6	Ash Combustible Composition	4-11
4-7	Boiler Heat Loss Efficiency -- Percent as Fired Fuel . .	4-15
4-8	Trace Element Partitioning -- Bottom Ash/Boiler Outlet Flyash	4-17
4-9	Trace Element Partitioning -- ESP Hopper Ash/ESP Outlet Flyash	4-19
4-10	Trace Element Size Fractioning Boiler Outlet	4-20
4-11	Trace Element Partitioning -- Vapor Phase/Solid Phase	4-22
4-12	Flue Gas Trace Element Concentrations at ESP Outlet . .	4-23
4-13	Trace Element Emissions (kg/min)	4-25
4-12	Elemental Mass Balance -- Outlet/Inlet	4-26
4-15	Sulfur Balance	4-28
4-16	Organic Analysis Schedule	4-30
4-17	Gravimetric and TCO Analyses of Ash Samples	4-31
4-18	Gravimetric and TCO Analyses of SASS Samples	4-33

TABLES (Concluded)

<u>Table</u>		<u>Page</u>
4-19	IR Results Summary of Total Extracts	4-34
4-20	IR Results of LC Fractions, XAD-2, Extract, Boiler Outlet	4-36
4-21	C ₁ - C ₆ Hydrocarbon Analyses	4-37

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of Mr. Jason Whitish and the power plant staff at Site A. Also the authors wish to acknowledge the assistance of Messrs. P. L. Langsjoen and J. E. Gabrielson of KVB and the KVB Site A field testing crew in this cooperative testing effort.

SECTION 1

INTRODUCTION

This report is part of a series of test reports resulting from the experimental testing task of the "Environmental Assessment of Stationary Source NO_x Control Technologies" (NO_x EA), Environmental Protection Agency Contract 68-02-2160. The NO_x EA is a 3-year program to: (1) identify the multimedia environmental impact of stationary combustion sources and combustion modification NO_x controls; and (2) identify the most cost-effective environmentally-sound NO_x controls for attaining and maintaining projected and current NO₂ air quality standards to the year 2000.

During the first year of the NO_x EA a preliminary environmental assessment concluded that emissions and operating data needed to perform adequate process engineering and environmental assessment activities were severely lacking in several key areas. Most noteworthy was the virtual absence of data on noncriteria flue gas emissions and liquid and solid effluents (Reference 1). In response to these identified data needs, NO_x EA field test programs were initiated. Source selection was based on a source/control priority listing developed in the preliminary environmental assessment. These test programs were designed to provide information on changes in emissions and operation due to NO_x controls. The NO_x EA field test program is outlined in Table 1-1.

This report describes the results of emission testing performed on a coal-fired traveling grate spreader stoker industrial boiler. The boiler is capable of producing 38 kg/s (300,000 lb/hr) of steam. During this program two furnace operating conditions were examined. The unit was run under normal operating conditions and particulate and trace element emissions were characterized using EPA Level 1 testing procedures. A second test was performed with increased overfire air (at constant overall

TABLE 1-1. NO_x EA FIELD TEST PROGRAM

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Coal-fired Utility Boiler	Kingston #6; 180 MW tangentia; twin furnace, 12 burners/ furnace, 3 elevations; cyclone, 2 ESP's for particulate control	Baseline Biased Firing (2) BOOS (2)	Continuous NO _x , SO ₂ , CO CO ₂ , O ₂ Inlet to 1st ESP: -- SASS -- Method 5 -- Method 8 -- Gas grab (C ₁ -C ₆ HC) Outlet of 1st ESP: -- SASS -- Method 5 -- Method 8 -- Gas grab (C ₁ -C ₆ HC) Bottom ash Hopper ash (1st ESP, cyclone) Fuel Operating data	TVA	Complete August 1977
Coal-fired Utility Boiler	Crist #7, 500 MW opposed wall fired; 24 burners, 3 elevations; ESP for particulate control	Baseline BOOS (2)	Continuous NO _x , CO, CO ₂ O ₂ Inlet ESP Inlet -- SASS -- Method 5 -- Method 8 -- Gas grab (C ₁ -C ₆ HC) ESP outlet -- SASS -- Method 5 -- Method 8 -- Gas grab (C ₁ -C ₆ HC) Bottom ash ESP hopper ash Fuel Operating data Bioassay	Exxon	Complete June 1978

TABLE 1-1. Continued

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Oil-fired Utility Boiler	Moss Landing #6; 740 MW opposed wall fired; 48 burners, 6 elevations	Baseline FGR + OFA	Continuous NO _x , CO, CO ₂ O ₂ SASS Method 5 Method 8 Gas grab (C ₁ -C ₆ HC) Fuel Operating data Bioassay	New test start	Complete September 1978
Coal-fired Industrial	Traveling grate spreader stoker, 38 kg/s (300,000 lb/hr), ESP for particulate control; wet scrubber for SO _x control	Baseline LEA + OFA	Continuous NO _x , CO, CO ₂ O ₂ Boiler exit: -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C ₁ -C ₆ HC) ESP outlet -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C ₁ -C ₆ HC) Bottom ash Cyclone hopper ash Fuel Operating data	KVB	Complete October 1977
Coal-fired Industrial	Traveling grate spreader stoker, 25 kg/s (200,000 lb/hr), ESP for particulate control;	Baseline LEA + High OFA	Continuous NO _x , SO ₂ , CO CO ₂ , O ₂ Boiler exit: -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C ₁ -C ₆ HC) ESP outlet -- SASS -- Method 5 -- Shell-Emeryville -- Gas grab (C ₁ -C ₆ HC) Bottom ash ESP hopper ash Fuel Operating data Bioassay	KVB	Complete February 1978

TABLE 1-1. Concluded

Source Category	Description	Test Points (Unit Operation)	Sampling Protocol	Test Collaborator	Status
Oil-fired Gas Turbine	T.H. Wharton Station, 60 MW GE MS 7001 C machine	Baseline Maximum water injection	Continuous NO _x , CO, CO ₂ O ₂ SASS Method 5 Method 8 Fuel Water Operating data Bioassay	General Electric	Complete, April 1978
Oil-fired Residential Heating Unit	Blueray Low NO _x furnace, Medford, New York	Continuous Cycling	Continuous NO _x , CO, CO ₂ O ₂ SASS Method 5 Method 8 Fuel	New test start with EPA-RTP	Complete, November 1978

excess air) to determine the effect on NO_x as well as particulate and trace element emissions.

The test program results will be used in both process analysis and source assessment modeling, concluded as part of the Environmental Assessment and Process Engineering task of the NO_x EA.

This testing program was performed in conjunction with KVB, Inc. During the testing program, KVB conducted the particulate (EPA Method 5) and sulfur species (Shell-Emeryville) tests, and operated the continuous monitoring van. Operating data collection, ash and coal sampling, source assessment sampling systems (SASS) operation and onsite gas chromatography was performed by Acurex. These tests are further documented as tests 34 and 35 in the KVB test program (Reference 2).

SECTION 2

TEST SITE DESCRIPTION

The unit tested in this study was a Foster Wheeler Limited boiler combined with a Detroit Stoker traveling grate spreader stoker. In this unit, coal is burned using a traveling grate spreader stoker. The total effective grate area is about 48 m^2 (515 ft^2). Coal is supplied through seven feeders located in the front wall of the furnace. The recommended coal sizing is 1.9 cm (0.75 in) $\times$ 0 with no more than 25 percent less than 0.634 cm (0.25 in). Overfire air (OFA) is injected into the furnace through two rows of ports located both on the back and front walls of the furnace. The overfire air is delivered using a fan that is independent of the forced draft system used for supplying undergrate air. Therefore the flow rates of undergrate air and overfire air can be set independently. A tubular air preheater is used to heat the undergrate air to about 450K (350°F). The overfire air is not preheated.

The Foster Wheeler steam generator was designed to produce 38 kg/s ($300,000 \text{ lb/hr}$) of saturated steam at a pressure of 2.3 MPa (320 psig). The boiler design specifications are given in Appendix A. The coal properties upon which the specifications are based are also listed in Appendix A.

A system diagram is presented in Figure 2.1. As shown in Figure 2.1, the gases and particulate exiting the boiler pass through the boiler-bank collector, air heater, mechanical ash collector, electrostatic precipitator (ESP), economizer and wet SO_2 scrubber before entering the stack. The design efficiency of the mechanical collector is 70 percent. The design efficiency of the ESP is 97.83 percent with one of the ESP's four fields out of service.

To improve system efficiency some of the flyash can be reinjected into the furnace. Particulate material collected in the boiler-bank collector, air heater collector, and mechanical collector may be

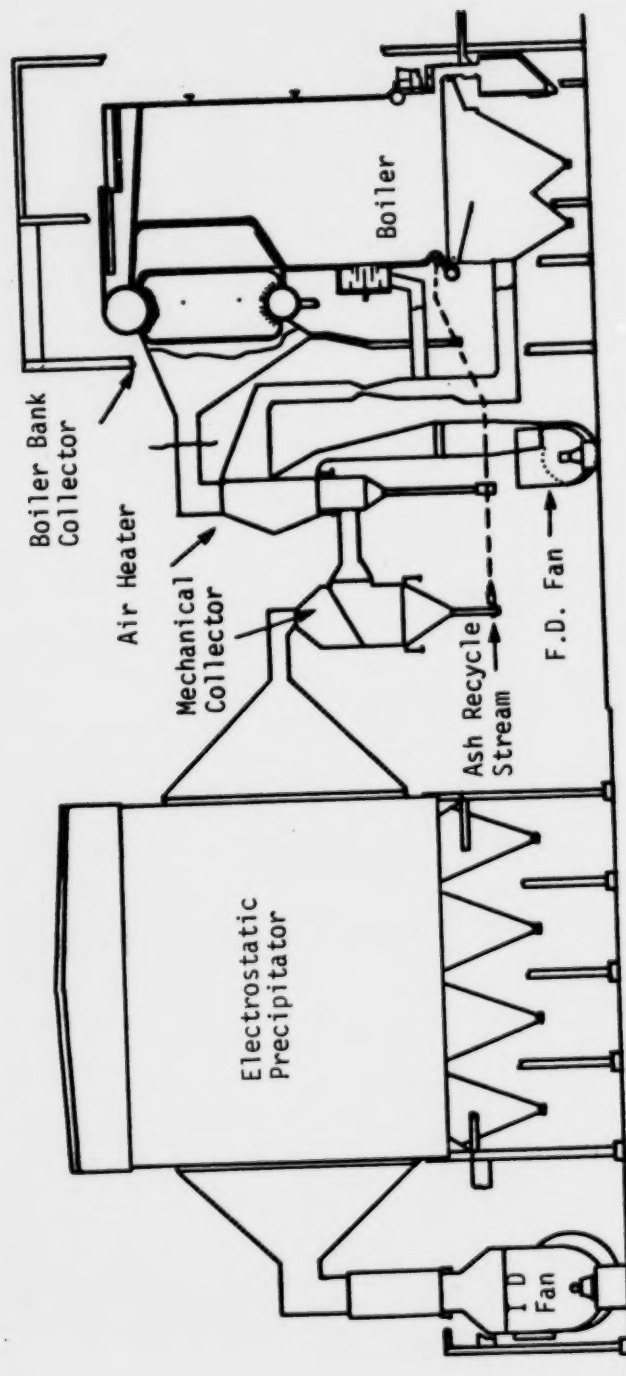


Figure 2-1. Boiler system diagram.

continuously reinjected. Reinjection rates are controlled by the boiler operator. The flyash reinjection ports are located on the rear wall of the furnace under the OFA ports. The reinjection air is supplied from the OFA fan.

SECTION 3

TEST PLAN

The objective of this test program was to examine changes in emissions and process operations as a result of applying combustion modification NO_x controls. In order to evaluate changes in emissions, the compositions of the influent and effluent streams were monitored. Process data were recorded periodically during each test so that changes in process operation could be examined.

3.1 UNIT OPERATION

Two modes of operation were examined during the testing period which spanned two days. During one test, the system was operated in the normal firing condition (Baseline). During the other test, the rate of undergrate air was reduced while the rate of overfire air was increased with the total air flow being held constant. In this manner, the quantity of NO_x exiting the boiler was reduced (Low NO_x condition) by promoting staged combustion conditions.

During each test, unit operation was to remain unchanged. Care was taken to maintain the same air rates and boiler load. During the Baseline test, the OFA pressure was maintained at 1.4 kPa (5.5 in H_2O). During the Low NO_x testing the OFA pressure was increased to 2.6 kPa (10.5 in H_2O). Using these pressure ratios, the rate of OFA injection in the Low NO_x test was approximately 138 percent of the Baseline test value.

During testing, the unit was run at about 78 percent of rated capacity. Operating parameters such as steam flow and temperature were recorded every 30 minutes to ensure a constant operating condition. These test parameters are listed in Appendix A.

A summary of the boiler system operating conditions is given in Table 3-1. As mentioned previously, the only difference between the Baseline and Low NO_x test was to be the method of furnace air distribution.

TABLE 3-1. BOILER OPERATING CONDITIONS

	Baseline	Low NO _x
Unit load - percent of maximum	79	78
Steam flow - kg/s (lb/hr)	29.80 (236,000)	29.51 (234,000)
Baseline normalized OFA rate - percent	100	138
Excess O ₂ - percent ^a	6.0	5.9
Coal flow - kg/s (lb/hr)	3.47 (27,500)	3.44 (27,250)
Heat input - MW (10 ⁶ Btu/hr)	85.6 (292)	82.3 (281)
Flue gas flow ^a - dscm/MJ (dscf/10 ⁶ Btu)	0.384 (14,300)	0.381 (14,200)

^aBoiler outlet

During the Low NO_x tests the overfire air rate was to be set at its maximum value. During the Baseline test the furnace air distribution was maintained at normal operating conditions.

The OFA flowrate and undergrate air flows were the only operating variables changed in the Low NO_x test. The OFA flow in the Low NO_x test was approximately 138 percent of the Baseline value. The unit load was held constant at 78 percent which corresponds to a steam flow of about 29.4 kg/s (234,000 lb/hr) of steam. Excess air was maintained between averages of 38 and 39 percent for the baseline and Low NO_x test respectively.

During the first test (Low NO_x condition), three of the ESP's four fields were out of service. These fields were intentionally removed from service during the second test to ensure that any difference in emissions between the tests would be due to the deliberately instituted boiler firing changes.

Throughout the testing, material collected in the mechanical ash collector was not reinjected. Rather it was routed into a surge hopper for removal. The variation in coal composition over the testing period was small. More specific details of unit operating conditions can be found in Appendix A.

3.2 SAMPLING AND ANALYSIS

The sampling and analysis procedures in this test program correspond to a modified EPA Level 1 protocol. The purpose of such Level 1 tests is to obtain preliminary environmental assessment information, identify problem areas, and provide the basis for setting priorities on streams, components and classes of materials for further consideration in overall assessment. As such, the results of the sampling and corresponding analysis procedures are quantitative within a factor of ± 2 to 3 (Reference 3). The sampling locations and sample analysis techniques used in this test program are described below.

3.2.1 Sampling

Six sampling locations were used during the testing program. The locations, with respect to the boiler system are shown in Figure 3.1. The following samples were collected:

- Coal at the fuel inlet
- Bottom ash

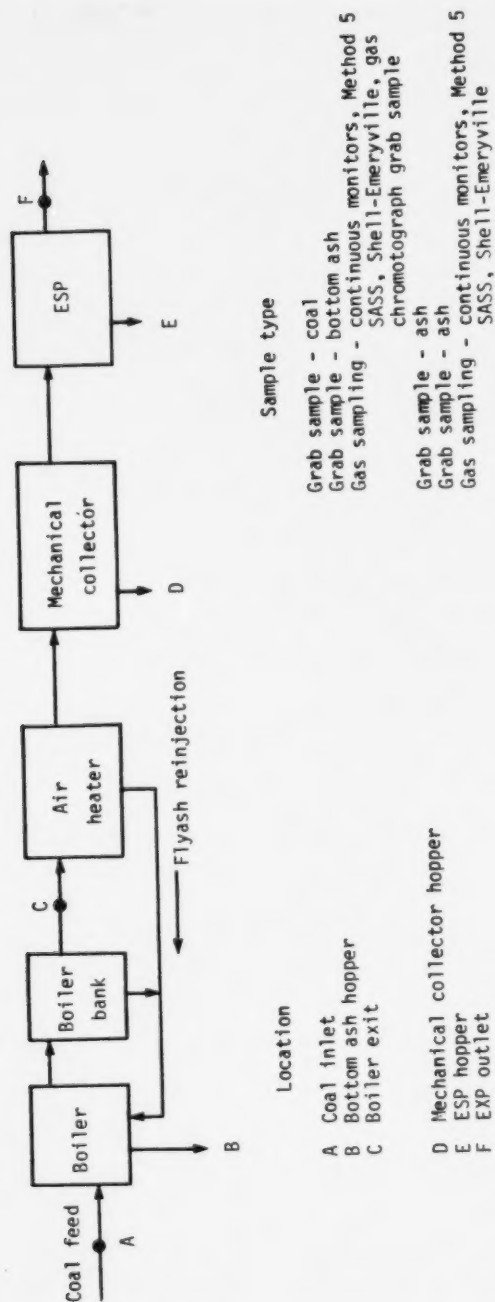


Figure 3.1. Sampling locations.

- Flue gas at the boiler outlet
 - Continuous monitors NO_x , SO_x , CO , CO_2 , and O_2
 - Source Assessment Sampling System (SASS), EPA Method 5 (particulate), and sulfur species (Shell-Emeryville)
- Mechanical collector ash
- ESP hopper ash
- Flue gas at the outlet of the ESP
 - Continuous monitors
 - SASS, EPA Method 5, and Shell-Emeryville

Batch Samples

Coal samples were taken from the seven feeder lines leading directly to the furnace. Samples were withdrawn at intervals ranging from 15 to 20 minutes throughout the tests. The collected samples were mixed and a representative sample was extracted from the mixture for subsequent analysis.

Bottom ash samples were collected after the end of each test. Between tests the ash hopper was emptied to be sure that the ash collected was solely from the test of interest.

Ash samples from the mechanical collector and ESP were collected periodically during the tests. These ash samples were taken from ports at the bottoms of the respective discharge hoppers.

Flue Gas Continuous Monitors

The continuous monitors for flue gas analysis were furnished by KVB, Inc. The gas samples were taken from four points along a cross-section of the ductwork at the boiler outlet. Samples were also withdrawn from a diametral traverse at a location between the ESP and the induced draft fan. Gas samples were taken continuously during each test. A description of the monitors used is given in Table 3-2.

Particulate and Sulfur Species

EPA Method 5 sampling trains were used to obtain particulate concentrations at the boiler outlet and the ESP outlet. The sulfur species SO_2 and SO_3 were determined using the Shell-Emeryville method (Reference 2).

Source Assessment Sampling System

Two Source Assessment Sampling Systems (SASS) trains were used simultaneously to sample the flue gas at the boiler outlet and at the

TABLE 3-2. CONTINUOUS MONITORS USED IN TESTING

Instruments	Technique	Measuring Range
1. NO, NO _x Analyzer	Chemiluminescent, negative pressure	0-2.5 ppm
		0-10 ppm
		0-25 ppm
Thermo Electron Model 10		0-100 ppm
		0-250 ppm
		0-1,000 ppm
		0-2,500 ppm
		0-10,000 ppm
2. CO Analyzer Beckman No. 3158	Nondispersive infrared absorption	0-500 ppm
		0-2,000 ppm
3. CO ₂ Analyzer Beckman No. 864	Nondispersive infrared absorption	0-5 %
		0-20 %
4. O ₂ Analyzer Teledyne No. 326A	Fuel cell	0-5 %
		0-10 %
		0-25 %

outlet of the electrostatic precipitator. These samples were used for trace element and organic species determinations in both vapor and condensed phases and also to provide particulate size distribution and trace element partitioning information.

The SASS train extracts the following samples:

Particulate:	>10 μm , 3-10 μm , 1-3 μm , 1 μm
Vapor phase:	XAD-2 porous polymer resin sorbent cartridge
	Aqueous condensate
	Hydrogen peroxide impinger
	Ammonium persulfate-silver nitrate impingers

A schematic of the SASS train is shown in Figure 3.2. The analysis protocol is given in Appendix B.

C₁-C₆ Hydrocarbons

A gas grab sample was collected at the boiler outlet. The sample was collected in a Tedlar bag and then used to determine C₁-C₆ hydrocarbon compounds by using an onsite gas chromatograph. A Carle Model 8500 portable gas chromatograph with flame ionization detector was used for this analysis.

3.2.2 Analysis

Table 3-3 lists the analyses performed on the data and samples collected during each test. Descriptions of these analyses are given in the following paragraphs.

Operating Data Analysis

The unit operating data collected during each test was used to calculate unit efficiency and to verify that unit operating parameters were being maintained according to the test plan. The average values for the operating parameters for each test are given in Appendix A. Unit efficiency was calculated using the Heat Loss Method, ASME Abbreviated Efficiency Test (Reference 4).

Inorganic Analyses

Trace element analyses for 25 selected trace elements were performed on the fuel, bottom ash, mechanical collector hopper ash, ESP hopper ash, SASS flyash, and SASS impinger solutions. The elements analyzed for were:

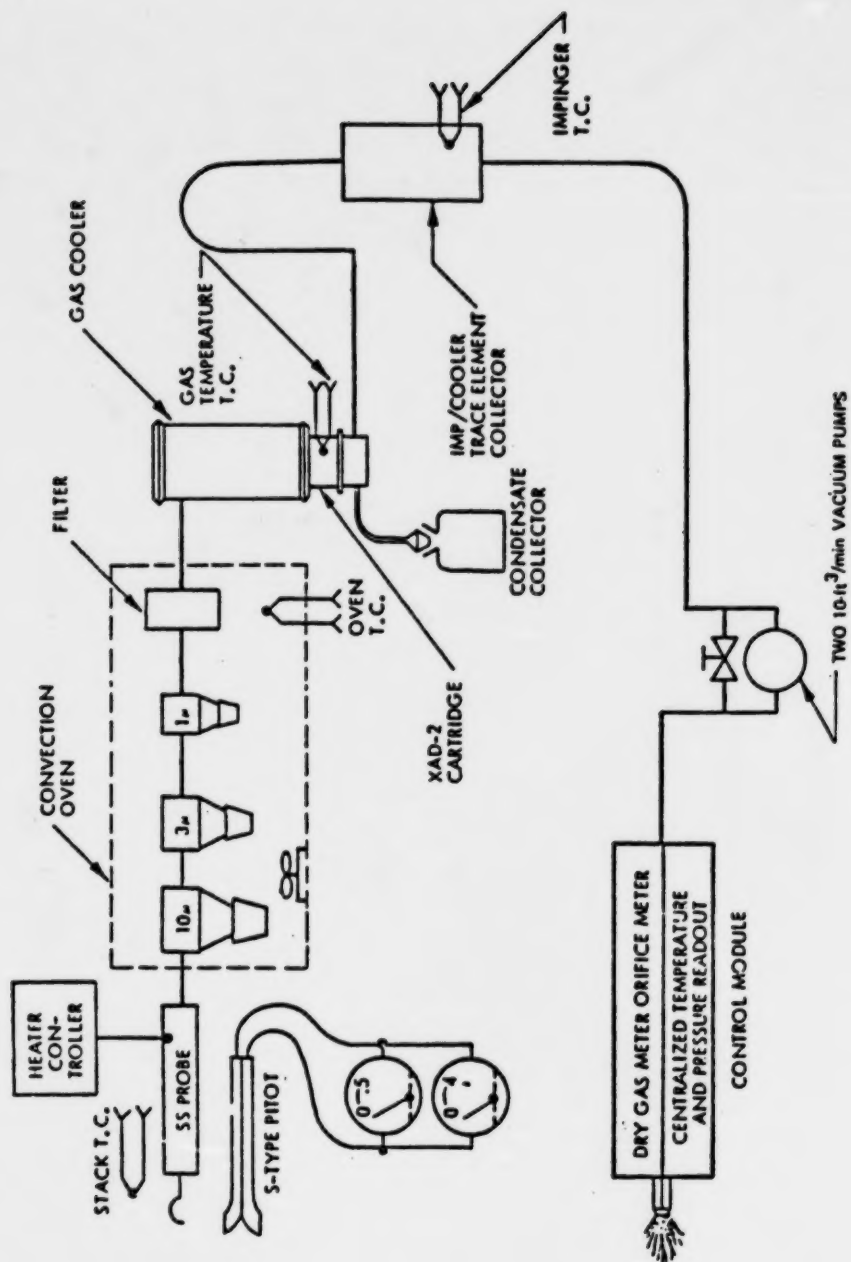


Figure 3.2. Source Assessment Sampling System (SASS) schematic (Reference 5).

TABLE 3-3. SAMPLE ANALYSIS

Location	
Coal Inlet	Proximate Analysis Ultimate Analysis Trace Elements
Bottom Ash Hopper	Percent Combustibles Trace Elements Organic Material
Flue Gas -- Boiler Outlet	Flue Gas Composition Particulate Loading Particulate Size Distribution Trace Elements Organic Material
Mechanical Collector Hopper	Percent Combustibles Trace Elements Organic Materials
ESP Hopper	Percent Combustibles Trace Elements Organic Material
Flue Gas -- ESP Outlet	Flue Gas Composition Particulate Loading Particulate Size Distribution Trace Elements Organic Material

Arsenic	Mercury
Barium	Molybdenum
Beryllium	Nickel
Bismuth	Selenium
Boron	Tellurium
Cadmium	Thallium
Chromium	Tin
Copper	Uranium
Iron	Vanadium
Lead	Zinc
Manganese	Zirconium

The procedure used for each trace element is outlined in Appendix B. Ash samples were also analyzed for selected anions; chloride, fluoride, nitrate, cyanide, and sulfate, plus ammonium as outlined in Appendix B. Proximate and ultimate analyses were conducted on the fuel samples. Flyash was examined for unburned combustible material.

Organic Analyses

Organic analyses were performed in accordance with the EPA Level 1 protocol (References 3 and 6). The analyses included flue gas C_1-C_6 hydrocarbons, organic material condensed on the ash samples, and organic material caught in the XAD-2 sorbent trap or retained in the condensate trap. Organic analysis procedures are also outlined in Appendix B.

SECTION 4

TEST PROGRAM RESULTS

Data from the test program provided information on unit operation, flue gas composition, particulate emissions, trace element emissions, sulfur species emissions, and organic material emissions. Data obtained are discussed in the report sections that follow.

4.1 UNIT OPERATION

Unit operation was held essentially constant throughout each test. Key operating variables were controlled throughout the test program so that tests could be compared to each other. A summary of the boiler operating conditions was given in Table 3-1. Detailed control room data for each test are presented in Appendix A.

As shown previously in Table 3-1, firing conditions were almost identical for the Baseline and Low NO_x tests. The respective excess air levels averaged 38 and 39 percent while the heat inputs averaged 78.5 and 79.4 MW.

NO_x control consisted solely of altering the proportions of overfire and undergrate air. The OFA rate for the Low NO_x condition was approximately 138 percent of the Baseline test.

The results of the coal analyses for each test are listed in Table 4-1. As stated previously, these coals were found to be very similar on the basis of ultimate analyses. The nitrogen and sulfur levels of the respective coals differ by less than 10 percent on either an as fired or thermal basis. In order to increase the confidence in the nitrogen and sulfur values resultant from ultimate analyses, a second analysis was performed on the coal fired during the Low NO_x test. The results of this analysis are also shown in Table 4-1. The nitrogen content ranges from 0.91 percent to 0.97 percent. The sulfur content shows a similar variation ranging from 0.34 percent to 0.40 percent.

TABLE 4-1. COAL ANALYSIS (PERCENT BY WEIGHT)

	Baseline	Low NO _x	
<u>Ultimate Analysis</u>			(Replicate)
Moisture	13.76	14.58	(9.21)
Carbon	60.87	60.06	(62.48)
Hydrogen	4.27	4.12	(4.22)
Nitrogen	0.97	0.95	(0.91)
Sulfur	0.34	0.36	(0.40)
Ash	7.18	7.88	(8.89)
Oxygen (by difference)	12.61	12.05	(13.89)
<u>Proximate Analysis</u>			
Moisture	13.76	14.58	(9.21)
Ash	7.18	7.88	(8.89)
Volatile Matter	34.88	34.43	(36.57)
Fixed Carbon	44.18	43.11	(45.33)
HHV ^a (MJ/kg)	24.670	23.910	(24.730)
(Btu/lb)	(10,615)	(10,289)	(10,642)

^aConstant volume determination

The size of the coal remained almost constant during the tests as reported in Reference 2. The size distribution of the coal was such that the mean size was approximately 0.64 cm (0.25 inch) with about 20 percent being greater than 1.14 cm (0.45 inch) and 80 percent being greater than 0.13 cm (0.05 inch).

4.2 FLUE GAS COMPOSITION

Table 4-2 shows the results of gas sampling at the boiler outlet and ESP outlet. First it should be noted that in both the Baseline and Low NO_x case the oxygen concentration measured at the boiler outlet is lower than the measured concentration at the ESP outlet. This indicates some air leakage in the ductwork, which might be expected.

The emission of NO_x at the boiler outlet was found to average 394 ppm at 3 percent O_2 for the Baseline test and 353 ppm at 3 percent O_2 for the Low NO_x test. This represents a reduction of NO_x in the Low NO_x test (compared to Baseline) of about 10 percent. As determined in test programs at this unit (Reference 2) NO_x is related more to excess air levels than to OFA-undergrate air apportioning.

The emission of CO also shows no significant change with the increase in OFA. CO concentrations were maintained at acceptable levels throughout the tests. The values at the boiler outlet were 313 ppm and 300 ppm (at 3 percent O_2) for the Baseline and Low NO_x tests.

Higher SO_2 levels were indicated in the Low NO_x tests. This should not be interpreted as being a result of the firing condition. Most likely, the raised SO_2 levels might be attributed to SO_2 measuring difficulties.

The CO_2 monitor was out of service during both tests. For calculation of furnace efficiency (Section 4.4), the CO_2 emission at the boiler outlet was assumed equal to 12.9 and 13 percent, being consistent with the O_2 levels measured during the Baseline and Low NO_x test.

There is some doubt about the results of the moisture determination at the boiler outlet during the Low NO_x test. It is unlikely that the moisture content of the flue gas would be substantially different than that found in the Baseline test. The low moisture levels might indicate leakage in the sampling train.

Likewise, there is also some doubt about the CO and SO_3 emissions measured at the ESP outlet. As mentioned previously, there was probably

TABLE 4-2. FLUE GAS COMPOSITION

	Baseline		Low NO _x	
	Boiler Outlet	ESP Outlet	Boiler Outlet	ESP Outlet
O ₂ (percent dry)	6.0	6.4	5.9	6.5
CO ₂ (percent dry)	00Sa	00Sa	00Sa	00Sa
H ₂ O (percent)	7.2	7.6	5.3	7.6
CO (ppm @ 3% O ₂ dry)	313	243	300	483
% baseline	100	100	96	199
NO _x (ppm @ 3% O ₂ dry)	394	382	353	315
% baseline	100	100	90	82
SO ₂ (ppm @ 3% O ₂ dry)	410	353	504	479
% baseline	100	100	123	135
SO ₃ (ppm @ 3% O ₂ dry)	7	2	10	12
% baseline	100	100	143	600

^aCO₂ meter out of service

air leakage in the ductwork between the boiler outlet and the ESP outlet. Because of air dilution of the flue gases, gaseous species concentrations at the ESP outlet should be lower than their counterparts measured at the boiler outlet (with the exception of O_2 concentration). The CO and SO_3 measurements made at the ESP outlet during the Low NO_x test are questionable, since the measured concentrations are higher than the respective concentrations measured at the boiler outlet.

For the purpose of calculating dry gas flows, the moisture content at the boiler outlet during the Low NO_x test was assumed to be 7.2 percent. This assumption effectively lowers the boiler outlet dry gas flowrate and increases particulate emissions slightly over the values obtained using the reported moisture content of 5.2 percent.

4.3 PARTICULATE EMISSIONS

Particulate emissions were measured simultaneously at the boiler outlet and the outlet of the ESP. Throughout both the Baseline and Low NO_x tests, the particulate catch of the boiler-bank collector and air heater collector were constantly reinjected into the furnace. There was no reinjection from the mechanical collector. Also the ESP was not operating at peak efficiency since three of its four fields were out of service during both tests.

Flue gas particulate loadings were obtained by using EPA Method 5 and SASS techniques. EPA Method 5 employs multipoint equal area sampling to measure particulate concentration. The SASS train is used primarily to obtain samples for trace specie analysis. In doing this, the SASS train provides particulate concentration and size distribution data from a single point sample. Since this single point is a point of average flue gas velocity, the SASS sample should be representative of the duct content. Simultaneous sampling at both the inlet and the outlet of the ESP gives both particulate concentration and particulate size distribution at the boiler outlet and outlet of the ESP. Comparisons of these data will show the effects of Low NO_x firing on particulate concentration, size distribution, and ease of collection.

Particulate concentration data from both the EPA Method 5 and SASS sampling trains are presented in Tables 4-3 and 4-4. The particulate concentrations are reported on a heat input basis ($\mu g/J$) and a volume concentration basis ($g/dscm$). The boiler outlet and ESP outlet concentrations

TABLE 4-3. METHOD 5 PARTICULATE CONCENTRATIONS

	Baseline	Low NO _x
Boiler Outlet -- $\mu\text{g/J}$	9.86	5.76
g/dscm	26.9	14.5
$(\text{lb}/10^6 \text{ Btu})$	22.9	13.4
ESP Outlet -- $\mu\text{g/J}$	0.013	0.024
g/dscm	0.040	0.063
$(\text{lb}/10^6 \text{ Btu})$	0.031	0.057
Normalized Boiler Outlet ^a	3.39	1.75
Normalized ESP Outlet ^a	0.004	0.007

^aParticulate flowrate ($\mu\text{g/J}$) divided by furnace input ash flow ($\mu\text{g/J}$)

TABLE 4-4. SASS PARTICULATE CONCENTRATIONS

	Baseline	Low NO _x
Boiler Outlet -- $\mu\text{g/J}$	1.59	11.70
g/dscm	4.34	29.40
$(\text{lb}/10^6 \text{ Btu})$	3.69	27.20
ESP Outlet -- $\mu\text{g/J}$	0.005	0.017
g/dscm	0.015	0.071
$(\text{lb}/10^6 \text{ Btu})$	0.012	0.064
Normalized Boiler Outlet ^a	0.55	3.56
Normalized ESP Outlet ^a	0.002	0.005

^aParticulate flowrate ($\mu\text{g/J}$) divided by furnace input ash flow ($\mu\text{g/J}$)

are also reported on a normalized basis (g flyash/g ash in coal) by dividing by the coal ash content ($\mu\text{g}/\text{J}$).

The EPA Method 5 testing shows normalized particulate loading at the boiler outlet was reduced by a factor of 2.0 in the Low NO_x test. The loading during the Baseline test was found to be $9.86 \mu\text{g}/\text{J}$ while that of the Low NO_x test was found to be $5.76 \mu\text{g}/\text{J}$. This situation could arise from two possible causes, namely:

- High OFA rates caused more complete combustion of suspended particulates
- Low undergrate air rates decrease the amount of flyash

The first hypothesis is supported by the results of combustibles analyses presented later.

At the ESP outlet, the situation appears to reverse with the normalized Low NO_x particulate emissions being higher by a factor of 1.5. The Method 5 particulate loading at the ESP outlet was found to be $0.013 \mu\text{g}/\text{J}$ for the Baseline test and $0.024 \mu\text{g}/\text{J}$ for the Low NO_x test.

The SASS particulate loadings are shown in Table 4-4. The SASS data obtained at the boiler outlet does not agree with the Method 5 data either quantitatively or qualitatively. The SASS loadings obtained at the ESP outlet agree fairly well with the Method 5 findings at that location.

The SASS particulate loadings are presented here for completeness only. The SASS train is intended for use primarily to obtain particulate sizing and composition information by collecting a single point sample. Particulate loading obtained from the single point SASS sampling is not expected to agree closely with the results of a multipoint Method 5 determination.

Particulate size distributions as measured by SASS are shown in Figure 4.1 and listed in Table 4-5. The aerodynamic cut diameters of the individual SASS cyclones have been determined to be 9.7, 3.7 and 1.5 microns (Reference 7). These cut diameters are based on a collection efficiency of 50 percent. Submicron particles are collected by a filter.

As shown in the figure, the size distribution at the boiler outlet for the Baseline and Low NO_x tests are noticeably different especially at the $10 \mu\text{m}$ cut point. The Baseline test shows that about 76 percent of the particles collected are greater than $10 \mu\text{m}$ while for the Low NO_x

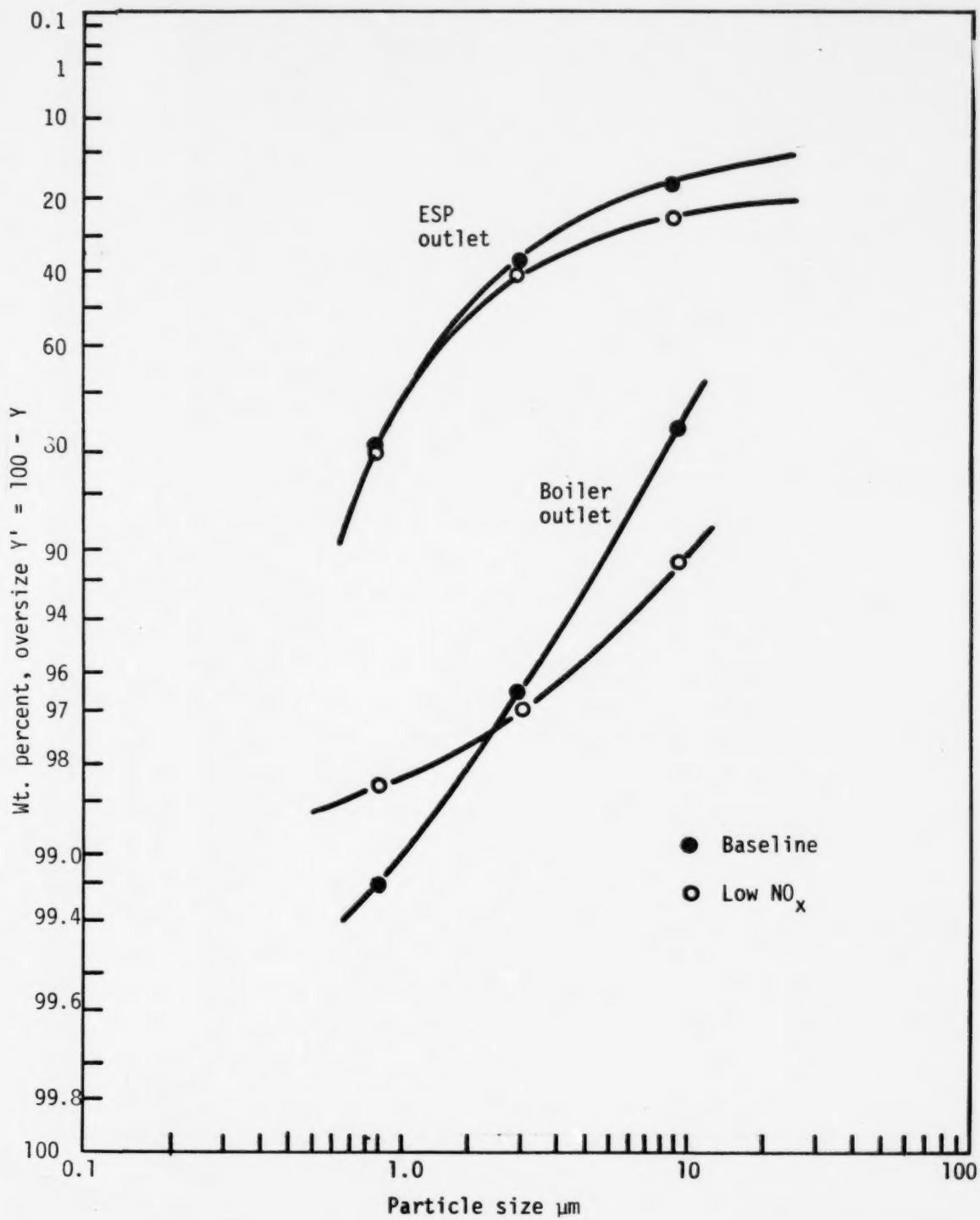


Figure 4.1. SASS particulate size distribution.

TABLE 4-5. SASS PARTICULATE SIZING
(CUMULATIVE WEIGHT PERCENT OVERSIZE)

	Baseline	Low NO _x
Boiler Outlet	Percent greater than stated size	
10 μ m Cyclone	76.0	90.7
3 μ m Cyclone	96.4	97.0
1 μ m Cyclone	99.2	98.4
Filter	100	100
ESP Outlet	Percent greater than stated size	
10 μ m Cyclone	17.8	24.5
3 μ m Cyclone	37.4	41.9
1 μ m Cyclone	79.2	80.2
Filter	100	100

test, about 91 percent are greater than 10 μm . The differences in size distribution become less noticeable at smaller sizes.

At the ESP outlet, the particle size distributions show less difference. The amount of particulate greater than 10 μm is about 18 percent for the Baseline test and 24 percent for the Low NO_x test. The amount of particulate greater than 1 μm is about 80 percent for both firing conditions.

As expected, the percentage of particles above 10 μm decrease after passing through the air heater collector, mechanical collector and ESP. However, it appears as if the particulate produced by the Low NO_x firing was larger in size than that produced during normal operation.

Combustibles in Refuse

Bottom ash, mechanical collector ash and ESP ash were analyzed for combustibles content. The results of these analyses are shown in Table 4.6.

The total amount of combustible material found in the bottom ash was 1.45 percent for the Baseline test and increased to 2.91 percent for the Low NO_x test. The results of the analyses of the mechanical collector ash showed that 87.4 percent of the material collected in the Baseline test and 67.6 percent of the material collected in the Low NO_x test was combustible. In the Baseline test 16.7 percent of the ESP catch was composed of combustibles. In the Low NO_x test 21.6 percent of the ESP catch was combustible.

The table shows a decrease in combustibles content between the mechanical collector and ESP. This is to be expected since the filtering action of the mechanical collector preferentially removes larger particles from the gas stream and these larger particles are likely to have reacted to a lesser extent.

The results indicate that the Baseline samples taken from the mechanical collector contain more combustible material than the respective Low NO_x sample. The reverse situation is found with the ESP hopper ash, and the bottom ash.

The increase in bottom ash combustibles in the Low NO_x test is probably due to less fuel being suspended above the grate with the decreased flow of undergrate air. Therefore, some of the larger particles could remain on the grate to be deposited into the bottom ash hopper.

The combustible content in the mechanical collector was found to be higher in the Baseline test. This is indicative of the beneficial effects

test, about 91 percent are greater than 10 μm . The differences in size distribution become less noticeable at smaller sizes.

At the ESP outlet, the particle size distributions show less difference. The amount of particulate greater than 10 μm is about 18 percent for the Baseline test and 24 percent for the Low NO_x test. The amount of particulate greater than 1 μm is about 80 percent for both firing conditions.

As expected, the percentage of particles above 10 μm decrease after passing through the air heater collector, mechanical collector and ESP. However, it appears as if the particulate produced by the Low NO_x firing was larger in size than that produced during normal operation.

Combustibles in Refuse

Bottom ash, mechanical collector ash and ESP ash were analyzed for combustibles content. The results of these analyses are shown in Table 4.6.

The total amount of combustible material found in the bottom ash was 1.45 percent for the Baseline test and increased to 2.91 percent for the Low NO_x test. The results of the analyses of the mechanical collector ash showed that 87.4 percent of the material collected in the Baseline test and 67.6 percent of the material collected in the Low NO_x test was combustible. In the Baseline test 16.7 percent of the ESP catch was composed of combustibles. In the Low NO_x test 21.6 percent of the ESP catch was combustible.

The table shows a decrease in combustibles content between the mechanical collector and ESP. This is to be expected since the filtering action of the mechanical collector preferentially removes larger particles from the gas stream and these larger particles are likely to have reacted to a lesser extent.

The results indicate that the Baseline samples taken from the mechanical collector contain more combustible material than the respective Low NO_x sample. The reverse situation is found with the ESP hopper ash, and the bottom ash.

The increase in bottom ash combustibles in the Low NO_x test is probably due to less fuel being suspended above the grate with the decreased flow of undergrate air. Therefore, some of the larger particles could remain on the grate to be deposited into the bottom ash hopper.

The combustible content in the mechanical collector was found to be higher in the Baseline test. This is indicative of the beneficial effects

TABLE 4-6. ASH COMBUSTIBLE COMPOSITION

Baseline	Bottom Ash	Mechanical Collector	ESP
Carbon - percent	1.37	86.78	16.47
Hydrogen - percent	0.08	0.66	0.21
Combustibles - percent	1.45	87.44	16.68
Heating value ^a - kJ/kg (Btu/lb)	488 (210)	29,463 (12,679)	5,621 (2,419)
Low NO _x			
Carbon - percent	2.55	67.09	21.45
Hydrogen - percent	0.36	0.49	0.16
Combustibles - percent	2.91	67.58	21.61
Heating value ^a - kJ/kg (Btu/lb)	981 (422)	22,724 (9,799)	7,280 (3,133)

^aAssuming a heating value of 33.7 MJ/kg (14,500 Btu/lb) for combustibles

that OFA has on combustion. The results show that an increase in OFA (Low NO_x test) increases the extent of combustion in the boiler. However, while an increase in OFA reduced the total flow of particulate exiting the boiler bank, the size of the particulate in the Low NO_x test was slightly larger than that found in the Baseline test.

4.4 OPERATING EFFICIENCY

In order to reduce some of the data collected in this study, it was necessary to quantify the mass flows of various streams, such as the bottom ash flow and reinjection flows. Particulate sampling was conducted at the boiler outlet and ESP outlet. This information was not sufficient to determine ash recycle ratios and ash hopper accumulation rates. Another study of this boiler system (Reference 2) conducted by KVB also did not produce accurate details of ash flows due to the complexity of the system. Hence, bottom ash flows have been assumed.

A typical value for the bottom ash flow in the traveling grate spreader stoker is 50 percent of the total ash. Of course this number is sensitive to variations in ash characteristics, furnace design and underfire air flow rate. Since actual unit data was not available, the 50 percent figure was used.

The other assumptions made were:

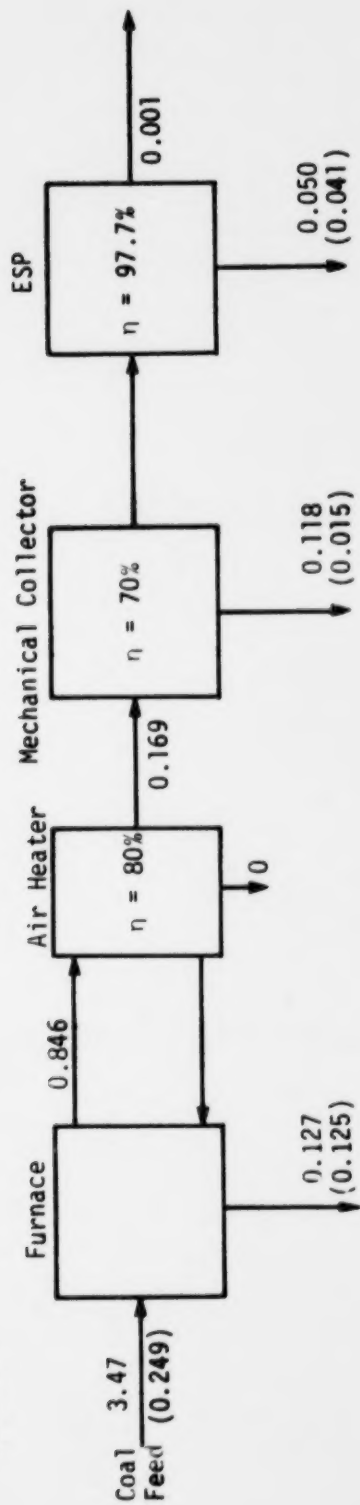
- The efficiency of the mechanical collector was equal to its design efficiency of 70 percent
- The efficiency of the air heater collector and the mechanical collector combined was equal to 94 percent as determined in other tests on this unit (Reference 2). Thus the air heater collector efficiency becomes 80 percent.

Given these assumptions, combined with the Method 5 particulate test data, system flow schematics were formulated and are shown in Figure 4.2.

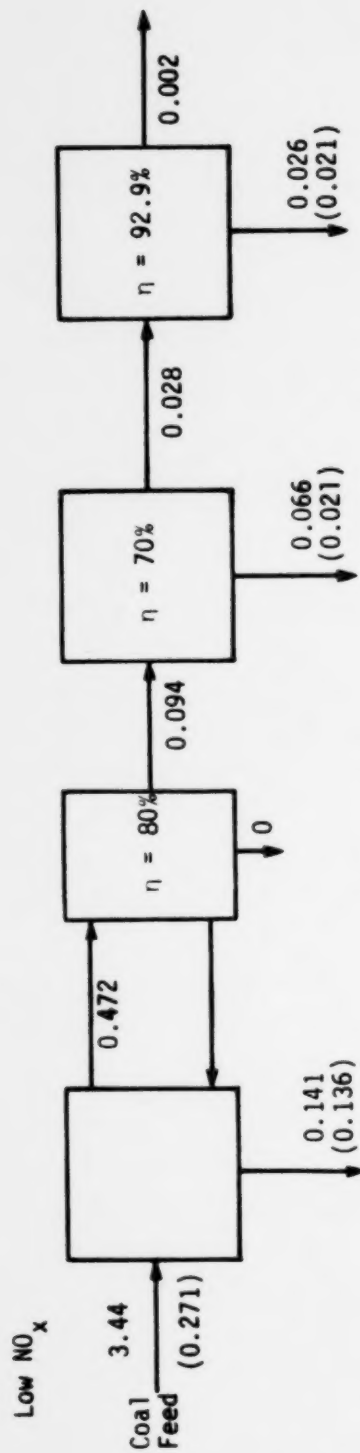
As shown in the Figure, during both tests 50 percent of the input ash was assumed to become bottom ash. The assumption of a constant flyash/bottom ash split in both tests does not account for any changes in the proportion of ash becoming bottom ash due to variations in undergrate air flow rates.

It was also assumed that all the particulate caught by the boiler-bank collector and air heater collector was reinjected into the

Baseline



Low NO_x



*Numbers in parenthesis indicate incombustible flow (kg/s)

Figure 4.2. System ash flows (kg/s)

furnace. This may not have been the case. Ash collected in these systems passes through a channel in which high velocity pick-up air flows. Any material not entrained in this stream is removed by the ash handling system. Thus not all of the air heater and boiler-bank ash may be injected, as assumed.

A unit efficiency calculation has been performed based on the assumed flows listed in Figure 4.2. A summary of the results is presented in Table 4-7. The efficiency calculation was performed using the ASME Abbreviated Efficiency Test (PTC 4.1-6). Details are given in Appendix A.

As shown in Table 4-7, the unit efficiency of the Baseline test is 77.80, which is lower than the Low NO_x test efficiency of 80.75. The largest factor causing the efficiency differences was the amount of heat loss due to combustible material in the flyash. The largest contributor in this category was the mechanical collector ash. The value of combustible content at this location was given as 87.4 percent versus 67.6 percent in the Low NO_x test. These results indicate the Low NO_x firing conditions give an improvement in boiler efficiency of about three percentage points. The majority of this increase is attributable to the reduced amount of particulate exiting the boiler.

4.5 TRACE ELEMENT CHARACTERIZATION AND EMISSIONS

Samples taken at the various sampling locations shown in Figure 3.1 were analyzed for selected trace elements and ionic species. The samples collected and analyzed were coal, bottom ash, flue gas and flue gas at the ESP outlet. The flue gas was sampled by using a SASS train. Grab samples were taken periodically from the other streams during the SASS test period. The detailed results of these analyses are presented in Appendix C.

Trace element concentrations reported for XAD-2, and impinger samples have been corrected for blank concentrations.

The 10 μm , 3 μm , 1 μm and filter SASS particulates collected at the boiler outlet were analyzed individually for trace elements. However, due to the small amount of particulate collected at the ESP outlet, separate analyses were not possible. For this reason the four SASS particulate fractions collected during the Baseline test were combined and analyzed. The ESP outlet samples were combined into two samples of analysis: 10 μm plus 3 μm , and 1 μm plus filter.

TABLE 4-7. BOILER HEAT LOSS EFFICIENCY^a -- PERCENT AS FIRED FUEL

Heat Loss	Baseline	Low NO _x
Dry gas	8.69	8.28
Moisture in fuel	1.58	1.70
H ₂ O from H ₂ combustion	4.42	4.33
Combustibles in refuse	4.87	2.30
Radiation	1.14	1.14
Unmeasured	1.50	1.50
Total loss	22.20	19.25
Efficiency	77.80	80.75

^aFrom ASME abbreviated test forms presented in Appendix A

Once the trace element concentrations were determined, trace element flowrates for each of the streams sampled could be computed. To calculate flows, the bottom ash/flyash split and collector efficiency assumptions outlined in Section 4.1 were used. Trace element flows in the bottom ash, ESP hopper ash and mechanical collector ash are thus approximations. The trace element flowrates are presented in Appendix D.

Solid Phase Trace Element Concentrations

Trace element concentrations in the bottom ash (Appendix C) were compared to those in the boiler outlet flyash stream to determine if solid phase trace element stream partitioning could be observed. As a result of this comparison, the trace elements were put into three groupings depending on whether: the material was partitioned about equally between bottom ash and flyash (EQ); the material was preferentially concentrated in the flyash (FA); or the material was concentrated in the bottom ash (BA).

The following criteria were used for categorizing:

- If the concentration of a particular element did not differ by a factor of two or greater when comparing flyash concentrations to bottom ash concentrations, the element was said to partition equally (EQ)
- If the concentration of a given element in one stream was two or more times greater than its concentration in the other stream, it was judged to partition in the former stream

As shown in Table 4-8, in the Baseline test those species found to concentrate in the bottom ash were barium, tin and nitrate. Those materials (Baseline) found to partition equally between bottom ash and flyash were: chromium, iron, manganese, and titanium. Arsenic, beryllium, boron, copper, molybdenum, nickel, selenium, zinc, fluoride and ammonium were found to selectively partition in the boiler outlet flyash.

Trace element partitioning did show some changes between the Low NO_x test and the Baseline test. The elements which exhibited changes in partitioning tendency were arsenic, beryllium, iron, manganese, titanium, and zinc. In general, Low NO_x firing caused less concentration in the flyash and more in the bottom ash. The partitioning tendencies of boron, chromium, fluoride and ammonium were found to concentrate in the flyash during Low NO_x testing. Arsenic and chromium partitioned about

TABLE 4-8. TRACE ELEMENT PARTITIONING -- BOTTOM ASH/BOILER OUTLET FLYASH

	Baseline	Low NO _x
Antimony	X	X
Arsenic	FA	EQ
Barium	BA	BA
Beryllium	FA	BA
Bismuth	X	X
Boron	FA	FA
Cadmium	X	X
Chromium	EQ	EQ
Cobalt	X	X
Copper	FA	X
Iron	EQ	BA
Lead	X	X
Manganese	EQ	BA
Mercury	X	X
Molybdenum	FA	X
Nickel	FA	X
Selenium	FA	FA
Tellurium	X	X
Thallium	X	X
Tin	BA	BA
Titanium	EQ	BA
Uranium	X	X
Vanadium	X	X
Zinc	FA	BA
Zirconium	X	X
Chloride	X	X
Fluoride	FA	FA
Cyanide	X	X
Nitrate	BA	BA
Sulfate	X	X
Ammonium	FA	FA

EQ = Material partitioned equally between
bottom ash and flyash

FA = Material preferentially concentrated in
mechanical collector hopper flyash

BA = Material preferentially concentrated in
bottom ash

X = Insufficient data

equally. The majority of these trace elements (barium, beryllium, iron, manganese, tin, zinc, titanium, and nitrate) concentrated in the bottom ash.

Table 4-9 lists the partitioning tendencies found at the ESP. In this table specie concentrations at the ESP flyash outlet were compared to their concentration in the ESP hopper ash. The same criteria used previously to determine partitioning tendencies were used to gauge ESP partitioning tendencies.

In the Baseline test, barium, chromium, lead, molybdenum, nickel, tellurium, thallium, tin, vanadium, and zinc were judged to concentrate selectively in the flyash stream. Titanium concentration was enhanced in the ESP catch and iron and manganese partitioned equally.

Due to small sample size, only limited information on trace element partitioning at the ESP was obtained during the Low NO_x tests. The results obtained show arsenic and beryllium and titanium concentrating in the ESP hopper ash while chromium and iron concentrated in the ESP outlet flyash.

Size Fractioning

Sampling at the boiler outlet and ESP outlet was conducted using a SASS train as mentioned in Section 3. Particulate samples collected at the boiler outlet (10 μ m, 3 μ m, 1 μ m, filter) were analyzed individually. Due to the small sample quantities collected at the ESP outlet, some fractions were combined for analysis. In the Baseline test, all four fractions were combined; in the Low NO_x tests, the 10 μ m plus 3 μ m and the 1 μ m plus filter were combined giving two samples for analyses. A tabulation of the analytical results is given in Appendix C.

The resultant SASS fraction analyses were examined to see if selective concentration of material with particle size could be determined. The results of these comparisons are shown in Table 4-10. In making comparisons, the concentration of an element in the largest size fraction was compared to the respective concentration in the smallest size fraction.

As shown in the table, most of the trace species tend to concentrate in the small particulates. This is observed both at the boiler outlet and ESP outlet. As expected, Low NO_x firing does not seem to have a significant effect on trace element size partitioning.

TABLE 4-9. TRACE ELEMENT PARTITIONING -- ESP HOPPER ASH/ESP OUTLET FLYASH

	Baseline	Low NO _x
Antimony	X	X
Arsenic	X	H
Barium	FA	X
Beryllium	X	H
Bismuth	X	X
Boron	X	X
Cadmium	X	X
Chromium	FA	FA
Cobalt	X	X
Copper	X	X
Iron	EQ	FA
Lead	FA	X
Manganese	EQ	H
Mercury	X	X
Molybdenum	FA	X
Nickel	FA	X
Selenium	X	X
Tellurium	FA	X
Thallium	FA	X
Tin	FA	X
Titanium	H	H
Uranium	X	X
Vanadium	FA	X
Zinc	FA	X
Zirconium	X	X
Chloride	X	X
Fluoride	X	X
Cyanide	X	X
Nitrate	X	X
Sulfate	X	X
Ammonium	X	X

EQ = Material partitioned equally between
bottom ash and flyash

H = Material preferentially concentrated
in mechanical collector hopper ash

FA = Material preferentially concentrated
in ESP outlet flyash

X = Insufficient data

TABLE 4-10. TRACE ELEMENT SIZE FRACTIONING BOILER OUTLET

	Baseline	Low NO _x	ESP Outlet Low NO _x
Antimony	X	X	X
Arsenic	S	E	X
Barium	S	S	S
Beryllium	L	L	L
Bismuth	X	X	X
Boron	X	X	X
Cadmium	S	S	S
Chromium	S	S	S
Cobalt	X	X	S
Copper	S	S	S
Iron	E	S	L
Lead	S	X	S
Manganese	S	S	S
Mercury	X	X	X
Molybdenum	X	X	S
Nickel	S	S	S
Selenium	S	S	S
Tellurium	S	X	X
Thallium	X	X	X
Tin	X	X	X
Titanium	S	S	S
Uranium	X	X	X
Vanadium	S	X	S
Zinc	L	S	S
Zirconium	X	X	X

L = Tending to concentrate in the large sizes
 S = Tending to concentrate in the smaller sizes
 E = Shows no size concentrating tendency
 X = Insufficient data

With few exceptions, all of the elements examined at the boiler outlet concentrated in the finer particulate. In the Baseline test, the exceptions were beryllium, iron and zinc. In the Low NO_x test, the exceptions were arsenic and beryllium. In both conditions, beryllium concentrated in the larger size fraction. In the Baseline test, iron was distributed about equally and zinc concentrated in the larger particles. In the Low NO_x test, arsenic was found to partition about equally.

At the ESP outlet, it was possible to look at size partitioning during the Low NO_x test. Again, it was found that most elements concentrated in the finer particulate. However, both beryllium and iron were found to selectively concentrate in the larger particulates.

Vapor Phase Trace Element Concentrators

Table 4-11 compares the ratio of vapor phase trace element flow (XAD-2 plus 1st, 2nd and 3rd impingers) to the flow of trace elements collected in the SASS cyclone and filter at the outlet of the ESP.

Many species concentrations were found to be below detectability limits. The lack of definitive analysis values prevents much information from being obtained about the amount of vapor phase material present. From Table 4-11, molybdenum, nickel and tin appear to exist largely in the vapor phase.

Outlet Emissions

Table 4-12 presents flue gas element concentrations measured at the ESP outlet. Anion measurements at the ESP outlet were not conducted due to the small amount of SASS particulate samples. The emissions listed in the table include both vapor and solid phase trace elements.

There were few changes in trace element emissions due to NO_x control implementation within the accuracy of the analysis. During the Low NO_x test, the concentrations of barium, beryllium, and boron decreased. The emissions of chromium, thallium and titanium were found to increase during the Low NO_x test.

The two species showing the largest change were beryllium and, titanium. Beryllium emissions decreased by about a factor of 40 during the Low NO_x tests. The emissions of titanium increased by a factor of approximately 10. In the case of beryllium, the increase in Baseline emissions was due to a high concentration being found in the XAD-2 cartridge. This may indicate an analysis error. If the XAD-2

TABLE 4-11. TRACE ELEMENT PARTITIONING -- VAPOR PHASE/SOLID PHASE

	Baseline	Low NO _x
Antimony	X	X
Arsenic	X	X
Barium	X	X
Beryllium	X	X
Bismuth	X	X
Boron	S	X
Cadmium	S	X
Chromium	S	X
Cobalt	X	X
Copper	S	X
Iron	S	S
Lead	S	X
Manganese	S	X
Mercury	X	X
Molybdenum	V	X
Nickel	V	X
Selenium	X	X
Tellurium	X	X
Thallium	X	X
Tin	X	V
Titanium	X	S
Uranium	X	X
Vanadium	S	X
Zinc	S	X
Zirconium	X	X

S = Element is found mostly in the solid phase
 V = Element is found mostly in the vapor phase
 X = Insufficient data

TABLE 4-12. FLUE GAS TRACE ELEMENT CONCENTRATIONS AT ESP OUTLET

Test	Baseline	Low NO _x
Heat input (% of baseline)	100	96
<u>Emissions $\mu\text{g}/\text{m}^3$ dry</u>		
NO _x (ppm @ 3% O ₂ dry)	6.32×10^5 (382)	5.21×10^5 (315)
SO ₂ (ppm @ 3% O ₂ dry)	8.18×10^5 (353)	1.10×10^6 (479)
SO ₃ (ppm @ 3% O ₂ dry)	5.78×10^3 (2)	3.45×10^4 (12)
CO (ppm @ 3% O ₂ dry)	2.46×10^5 (243)	4.86×10^5 (483)
CO ₂ (%)	00S ^a	00S ^a
O ₂ (%)	(6.4)	(6.5)
Particulate ($\mu\text{g}/\text{dscm}$)	4.0×10^4	6.3×10^4
Antimony	$<1.90 \times 10^1$	<3.17
Arsenic	3.19	<7.03
Barium	4.24×10^2	7.03×10^1
Beryllium	3.76	$<9.65 \times 10^{-2}$
Bismuth	$<2.43 \times 10^1$	<6.69
Boron	9.14×10^2	3.49×10^2
Cadmium	6.06	$<1.71 \times 10^1$
Chromium	1.72×10^1	1.48×10^2
Cobalt	9.19	$<4.81 \times 10^1$
Copper	2.85×10^1	$<9.77 \times 10^1$
Iron	1.09×10^3	1.91×10^3
Lead	$<5.74 \times 10^1$	$<1.78 \times 10^2$
Manganese	3.18×10^1	$<7.73 \times 10^1$
Mercury	$<3.70 \times 10^{-1}$	$<1.57 \times 10^{-2}$
Molybdenum	1.02×10^1	<8.02
Nickel	3.43×10^1	$<1.42 \times 10^2$
Selenium	3.24×10^1	4.53×10^1
Tellurium	1.11	<5.53
Thallium	$<3.43 \times 10^1$	$<3.74 \times 10^2$
Tin	8.36	$<2.18 \times 10^2$
Titanium	1.22	5.78×10^2
Uranium	--	--
Vanadium	8.72	$<1.72 \times 10^1$
Zinc	6.27×10^1	3.52×10^1
Zirconium	--	--

^aCO₂ monitor out of service

concentration was set equal to zero, then the Baseline emission of beryllium would decrease by a factor of about 140. The concentration of titanium found in the SASS samples are more or less uniform for each set of sample fractions, and therefore an error in analyses is less likely to have occurred.

The flow of individual trace elements are reduced as they pass through the particulate boiler flyash collection systems. However, the efficiency of removal is not the same for all species. This is illustrated in Table 4-13.

Table 4-13 shows the flows of individual species (kg/min -- vapor plus solids) as they exit the boiler-bank, and exit the ESP. The total particulate flows are also shown. The reduction of particulate by the mechanical collector and ESP combined was 99.9 percent during the Baseline test and 99.6 percent during the Low NO_x test. The amount of trace element reduction ranges from about 100 percent for titanium to about 50 percent for boron.

Elemental Mass Balance

A system species mass balance was performed using trace element flow data (Appendix D). These calculations do not include elemental catches in the XAD-2 or impingers since the majority of these analyses did not produce definitive values. Impinger and XAD-2 concentrations were taken to be zero.

Bottom ash, mechanical collector hopper ash and ESP ash flows have been estimated as described in Section 4.2 (illustrated in Figure 4.2). The flyash/bottom ash split was assumed to be 50/50. The mechanical collector efficiency was set at its design efficiency of 70 percent. Based on these figures, ash balance closure is 73 percent for the Baseline test and 67 percent for the Low NO_x condition.

The results of the elemental balances are presented in Table 4-14. In the two tests, the average ratio of outlet flow to inlet flow is about 0.6 to 0.7, excluding value obtained for tin and in the Baseline tests. The closure values for nickel and zinc are greater than twice the average while the values obtained for barium and titanium and vanadium are much less than the average.

The closure on all of the species balances can be influenced by the choice of the flyash/bottom ash split. The degree of sensitivity to this

TABLE 4-13. TRACE ELEMENT EMISSIONS (kg/min)

	Baseline			Low NO _x	% Reduction
	Boiler Outlet	ESP Outlet	Boiler Outlet	ESP Outlet	
Particulate	50.7	0.069	28.32	0.12	99.6
Antimony	<5.1 x 10 ⁻⁵	<3.6 x 10 ⁻⁵	<3.3 x 10 ⁻⁵	<5.4 x 10 ⁻⁸	--
Arsenic	2.7 x 10 ⁻⁴	6.1 x 10 ⁻⁶	1.4 x 10 ⁻⁵	<1.2 x 10 ⁻⁵	>14.3
Barium	5.8 x 10 ⁻³	<8.1 x 10 ⁻⁴	<7.1 x 10 ⁻⁴	1.2 x 10 ⁻⁴	<83.1
Beryllium	1.3 x 10 ⁻⁴	7.2 x 10 ⁻⁶	1.3 x 10 ⁻⁵	<1.7 x 10 ⁻⁷	>98.7
Bismuth	<2.3 x 10 ⁻³	<4.7 x 10 ⁻⁵	<1.4 x 10 ⁻³	<1.2 x 10 ⁻²	--
Boron	3.3 x 10 ⁻³	1.8 x 10 ⁻³	2.4 x 10 ⁻³	6.0 x 10 ⁻⁴	75.0
Cadmium	<1.7 x 10 ⁻⁴	1.1 x 10 ⁻⁵	<6.2 x 10 ⁻⁵	<2.9 x 10 ⁻⁵	--
Chromium	1.6 x 10 ⁻³	3.3 x 10 ⁻⁵	6.0 x 10 ⁻⁴	2.5 x 10 ⁻⁴	58.3
Cobalt	<5.7 x 10 ⁻⁴	<1.8 x 10 ⁻⁵	<3.6 x 10 ⁻⁴	<8.3 x 10 ⁻⁵	--
Copper	4.9 x 10 ⁻³	<3.9 x 10 ⁻⁵	<5.9 x 10 ⁻⁴	<1.7 x 10 ⁻⁴	--
Iron	1.3	2.1 x 10 ⁻³	1.3 x 10 ⁻¹	3.3 x 10 ⁻³	97.5
Lead	<2.4 x 10 ⁻⁴	<1.1 x 10 ⁻⁴	<1.2 x 10 ⁻³	<3.1 x 10 ⁻⁴	--
Manganese	2.0 x 10 ⁻²	6.1 x 10 ⁻⁵	2.8 x 10 ⁻³	<1.3 x 10 ⁻⁴	>95.4
Mercury	--	--	--	--	--
Molybdenum	<2.8 x 10 ⁻⁴	2.0 x 10 ⁻⁵	<9.1 x 10 ⁻⁵	<1.4 x 10 ⁻⁵	--
Nickel	1.8 x 10 ⁻³	6.5 x 10 ⁻⁵	<7.1 x 10 ⁻⁴	<2.4 x 10 ⁻⁴	--
Selenium	2.9 x 10 ⁻⁴	6.2 x 10 ⁻⁵	1.5 x 10 ⁻⁴	7.8 x 10 ⁻⁵	48.0
Tellurium	<7.8 x 10 ⁻⁵	<2.1 x 10 ⁻⁶	<4.6 x 10 ⁻⁵	<9.5 x 10 ⁻⁶	--
Thallium	<3.6 x 10 ⁻³	<6.6 x 10 ⁻⁵	<2.8 x 10 ⁻³	<6.4 x 10 ⁻⁴	--
Tin	5.4 x 10 ⁻⁴	1.6 x 10 ⁻⁵	<7.7 x 10 ⁻⁵	3.8 x 10 ⁻⁴	--
Titanium	1.6 x 10 ⁻¹	<2.3 x 10 ⁻⁶	2.0 x 10 ⁻²	9.9 x 10 ⁻⁴	95.1
Uranium	--	--	--	--	--
Vanadium	<1.7 x 10 ⁻³	<1.7 x 10 ⁻⁵	<9.2 x 10 ⁻⁴	<3.0 x 10 ⁻⁵	--
Zinc	3.4 x 10 ⁻³	1.2 x 10 ⁻⁴	<4.8 x 10 ⁻⁴	<6.1 x 10 ⁻⁵	--
Zirconium	--	--	--	--	--
Chloride	<2.9 x 10 ⁻³	--	1.2 x 10 ⁻³	--	--
Fluoride	4.0 x 10 ⁻³	--	1.0 x 10 ⁻³	--	--
Cyanide	<5.0 x 10 ⁻⁴	--	9.4 x 10 ⁻⁵	--	--
Nitrate	1.3 x 10 ⁻⁵	--	<6.0 x 10 ⁻²	--	--
Sulfate	--	--	--	--	--
Ammonium	6.6 x 10 ⁻⁴	--	3.2 x 10 ⁻⁴	--	--

TABLE 4-14. ELEMENTAL MASS BALANCE -- OUTLET/INLET

Test	Baseline	Low NO _x
Antimony	--	--
Arsenic	--	--
Barium	0.09	0.12
Beryllium	0.38	0.55
Bismuth	--	--
Boron	--	--
Cadmium	--	--
Chromium	0.66	1.22
Cobalt	0.12	0.15
Copper	0.57	0.59
Iron	0.69	0.56
Lead	--	--
Manganese	0.63	0.52
Mercury	--	--
Molybdenum	--	--
Nickel	1.71	2.05
Selenium	2.02	0.67
Tellurium	--	--
Thallium	--	--
Tin	63.81	0.71
Titanium	0.27	0.49
Uranium	--	--
Vanadium	0.05	0.06
Zinc	1.11	0.79
Zirconium	--	--

ratio can be seen in Table 4-8. Elements that concentrate in the bottom ash are most sensitive while elements that concentrate in the flyash are least sensitive. Barium and titanium were found to concentrate in the bottom ash while nickel and zinc were found to concentrate in the flyash (Table 4-8).

Generally both ash flow closure and specie closure could be improved somewhat by assuming a greater percentage of ash as bottom ash.

Trace Element Emissions Summary

From the information presented in the previous section it was found that trace element partitioning tendencies in the furnace did change slightly as a result of Low NO_x firing. The trend was for more of the materials to concentrate in the bottom ash with increased OFA (decreased undergrate air). The changes are probably due to changes in above-grate suspended particulate.

During the Low NO_x test, ESP emissions of bismuth, chromium, and titanium were higher than the respective emissions found in the Baseline test. The emissions of beryllium, boron and zinc were found to be lower during the Low NO_x test.

4.6 SULFUR SPECIES EMISSIONS

Sulfur species were analyzed in all sample streams according to the following protocol:

- Coal -- sulfur by ultimate analysis
- Bottom ash -- sulfur by turbidimetric method
- Flue gas at boiler outlet -- SO_2 and SO_3 by Shell-Emeryville Method and sulfate on particulate by turbidimetric method
- Mechanical collector ash -- sulfate by turbidimetric method
- ESP ash -- sulfate by turbidimetric method
- Flue gas at ESP outlet -- SO_2 and SO_3 by Shell-Emeryville Method and sulfate on particulate by turbidimetric method

Assuming a 50/50 bottom ash to flyash ratio, a sulfur balance could thus be performed considering all sample streams.

The result of the sulfur balance is shown in Table 4-15. The results show very little sulfur being present in any of the ash hoppers. The sulfur remains largely in the gas and exits the system as SO_2 . As

TABLE 4-15. SULFUR BALANCE

Test	Baseline	Low NO _x
Sulfur in coal ng/J	138	151
Sulfur in bottom ash ng/J	0.002	0.002
Sulfur in mechanical collector ash ng/J	<0.002	0.006
Sulfur as SO ₂ /SO ₃ /SO ₄ at boiler outlet ng/J	184	213
Recovery at ESP inlet %	133	141
Sulfur in ESP ash ng/J	0.002	0.01
Sulfur as SO ₂ /SO ₃ /SO ₄ at ESP outlet ng/J	153	196
Recovery at ESP outlet %	111	130

shown in the table, 90 to 120 percent of the sulfur is recovered at the ESP outlet.

The percentages of sulfur recovered at the boiler outlet are inconsistent with expectations (much greater than 100 percent). This seems to indicate an error being present in either the coal sulfur analysis or SO₂ measuring technique.

4.7 ORGANIC ANALYSES

Organic analyses were performed on selected samples according to the EPA Level 1 protocol as outlined in Appendix B (References 3 and 5). The samples were analyzed as follows: First they were extracted with methylene chloride in a Soxhlet apparatus. The extracts were then subjected to total chromatographable organic (TCO) and gravimetric analyses which determine species with boiling points in the ranges of 373K (212F) to 573K (572F) and greater than 573K respectively. Infrared spectra were also performed. If certain TCO and gravimetric requirements were met, further analyses by liquid column chromatography, with infrared and mass spectral analyses of the fractions eluted from the column, were performed. In addition, Baseline test flue gas C₁ to C₆ hydrocarbon compounds were analyzed onsite by gas chromatography. Equipment problems prevented these analyses for the Low NO_x test. The analyses performed are given in Table 4-16. A discussion of the analytical results follows.

4.7.1 Total Chromatographable Organics (TCO) and Gravimetric Analyses of Organic Extracts

Total chromatographable organics (TCO) and gravimetric analyses were performed on organic extracts of the samples from the Baseline and Low NO_x tests. The samples analyzed were the bottom ash, mechanical collector hopper ash, electrostatic precipitator hopper ash, the particulate samples collected by the SASS train at the boiler outlet, and the combined XAD-2 sorbent and organic module condensate samples collected by the SASS trains at the boiler outlet and the ESP outlet.

The analysis results of the ash samples are presented in Table 4-17. The range of the total extractable organic content (TCO plus gravimetric) varies from sample to sample and between the two firing conditions. In the Baseline test, less than 1.9 µg/g of extractable organic material was found in the bottom ash while 328 µg/gm was found in the flyash at the mechanical collector. In the Low NO_x test, the

TABLE 4-16. ORGANIC ANALYSIS SCHEDULE

Test	Sample Type	TCO	Gravimetric	IR	Other
Baseline	Bottom Ash	X	X	X	
	Boiler Outlet Flue Gas XAD-2	X	X	X	C ₁ -C ₆ Gas chromatography (on-site)
	10 μ + 3 μ	X	X	X	LC Separation, IR of fractions, GCMS for POM
	Mechanical Collector	X	X	X	
	ESP Hopper	X	X	X	
	ESP Outlet Flue Gas XAD-2	X	X	X	
Low NO _x	Bottom Ash	X	X	X	
	Boiler Outlet Flue Gas XAD-2	X	X	X	LC Separation, IR of fractions, GCMS for POM
	10 μ + 3 μ	X	X	X	
	Mechanical Collector	X	X	X	
	ESP Hopper	X	X	X	

TABLE 4-17. GRAVIMETRIC AND TCO ANALYSES OF ASH SAMPLES

Test	Sample Type	Gravimetric Results (mg)	TCO Results (mg)	Total Organics in Extract (mg)	Weight of Samples Extracted (g)	Extractable Organics in (µg/g)	Unburned Combustible Material (%)
Baseline	Bottom ash Mechanical Collector ESP Hopper	<0.1	<0.1	<0.1	53.4	<1.9	1.4
		2.5	<0.1	2.5	7.6	327.7	87.4
		1.0	0.5	1.5	19.9	75.5	16.7
Low NO _x	Bottom Ash Mechanical Collector ESP Hopper	0.9	<0.1	0.9	27.0	33.3	2.9
		<0.1	<0.1	<0.1	8.1	<12.4	67.6
		0.7	0.3	1.0	14.2	70.5	21.6

extractable organic content of the bottom ash increases to 33.3 $\mu\text{g/gm}$ and is lower in the mechanical collector, being less than 12.4 $\mu\text{g/gm}$. The analyses of the ESP hopper ash samples indicated extractable organic contents of 75.5 $\mu\text{g/g}$ and 70.5 $\mu\text{g/g}$ in the Baseline and Low NO_x tests respectively.

Comparing the extractable organic material concentrations to the unburned combustible material in the ash samples shows that the organic material emissions generally increase with levels of unburned material in the ash. The small amount of organic material in the bottom ash corresponds to a low level of unburned material. There is an apparent anomaly in the mechanical collector ash data for the Low NO_x test. With the high amount of combustible material, a greater quantity of organic material would be expected. Hence, the 12.4 $\mu\text{g/g}$ organic material concentration is suspect. This may be related to the small sample quantity extracted. In the ESP hopper ash samples the relatively low level of organic material corresponds to the relatively low levels of unburned combustible material.

The results of the gravimetric and TCO analyses of SASS samples are presented in Table 4-18. Analyses of SASS particulate fractions at the ESP outlet were not performed due to insufficient sample quantities.

The results in Table 4-18 show several things. The emissions of organics in the vapor phase at the boiler outlet are much lower than the emissions of organics condensed on particulate in the Baseline test. The reverse situation is found in the Low NO_x tests. In addition, the total organic emissions at the boiler outlet were found to be much higher in the Low NO_x test.

The emissions of organics at the ESP outlet are lower than those found at the boiler outlet ($\mu\text{g/dscm}$) in both tests. This reduction amounts to about 40 percent in the Baseline test and about 10 percent in the Low NO_x test. The organic material emissions found in the Low NO_x test are greater than the Baseline value by about 80 percent.

4.7.2 Infrared Spectra of Total Sample Extracts

The results of the infrared spectra determinations for the total sample extracts are given in Table 4-19. With the exception of the ESP outlet XAD-2 extract, the Baseline and Low NO_x sample spectra are the same. In the ESP outlet XAD-2 extract, the Baseline test shows carboxylic

TABLE 4-18. GRAVIMETRIC AND TCO ANALYSES OF SASS SAMPLES

Test	Sample Type	Gravimetric Result (mg)	TCO Results (mg)	Total Organics in Extract (mg)	Wt. of Sample Extracted (g)	Total Wt. of Sample (g)	Organics in Total Sample		
							(mg)	µg/g	g/dscm
Baseline	Boiler Outlet 10µ + 3µ XAD-2	0.2 19.3	0.5 1.7	0.7 21.0	18.9 per test	53.6 --	2.0	37.4	156
							21.0	--	1637
Low NO _x	Boiler Outlet 10µ + 3µ XAD-2	1.3 13.2	0.8 1.9	2.1 15.1	13.0 per test	217 --	35.0	162	4611
							15.1	--	1989
Baseline	ESP Outlet XAD-2	10.0	7.7	17.1	per test	--	17.7	--	1003
Low NO _x	ESP Outlet XAD-2	15.4	13.4	28.8	per test	--	28.8	--	1793

TABLE 4-19. IR RESULTS SUMMARY OF TOTAL EXTRACTS

Sample	Baseline Test	Low NO _x Test
Bottom Ash	Possible carboxylic acid	Possible ester or ether
Boiler Outlet SASS		
10 μ m + 3 μ m	Aliphatic compounds present	Aliphatic compounds present
XAD-2	Carboxylic acid present	Carboxylic acid present
XAD-2 Gravimetric Fraction	Some aliphatic compounds weak aromatic indication	Weak spectrum, aliphatic compounds present
Mechanical Collector Ash	No significant peaks	Weak spectrum
ESP Hopper Ash	Aliphatic compounds present	Aliphatic compounds present
ESP Outlet SASS XAD-2	Carboxylic acids, some aromatics present	Possible amide and aromatics present

acid and some aromatics while the Low NO_x test shows possible amide and aromatic compounds present. The IR spectra are given in Appendix E.

4.7.3 Column Chromatography

None of the samples contained a sufficient quantity of organic material to warrant separation by liquid column chromatography and further analyses of the fractions per Level 1 criteria. However, the XAD-2 extract samples from the SASS trains at the boiler outlet for both Baseline and Low NO_x tests were separated and infrared spectra were determined. In addition, fractions 2 and 3 were analyzed for specific polycyclic organic compounds by gas chromatography/mass spectrometry (GCMS). These compounds were:

- 7,12 Dimethylbenz(a)anthracene
- Dibenzo(a,h)anthracene
- Benzo(c)phenanthrene
- 3-Methyl cholanthrene
- Benzo(a)pyrene
- Dibenzo(a,i)pyrene
- Dibenzo(c,g)carbazole

The results of the GCMS analyses indicated that none of the above compounds were detected at levels of 2 µg/dscm for the Baseline test and 3 µg/dscm for the Low NO_x test. This conclusion is reinforced by the infrared spectra showing no presence of aromatic compounds in any of the fractions, including fractions 2 and 3. The total sample spectra did show weak indication of aromatic compound presence. This was apparently not in the fractionation. The summary results of the infrared analyses are given in Table 4-20. The IR spectra are presented in Appendix E. The major differences between the Baseline and Low NO_x samples appear in fraction 6. The Baseline sample contains a small amount of an acid or alcohol while the Low NO_x sample contains possible aliphatic ketone.

4.7.4 C₁ to C₆ Flue Gas Hydrocarbon Analysis

Onsite analyses of C₁ to C₆ flue gas hydrocarbons at the boiler outlet were conducted for the Baseline test. Due to equipment operating problems, samples from the first day of testing, the Low NO_x test, were not analyzed. The analysis shows approximately 97 ppm-dry (as CH₄) C₁ to C₆ hydrocarbons present in the flue gas. The results of the analyses are shown in Table 4-21.

TABLE 4-20. IR RESULTS OF LC FRACTIONS, XAD-2, EXTRACT, BOILER OUTLET

Fraction	Baseline Test	Low NO _x Test
1	Weak spectrum, aliphatic compounds present	Weak spectrum, aliphatic compounds present
2	No peaks other than those present in blank	Weak spectrum, aliphatic compounds present
3	Aliphatic compounds present	Weak spectrum, aliphatic compounds present
4	No peaks other than those present in blank	Aliphatic compounds present
5	Weak spectrum, aliphatic compounds present	No peaks other than those present in blank
6	Aliphatic compounds present possible acid or alcohol	Aliphatic compounds present, possible aliphatic ketone and acid or acid with strong hydrogen bonding
7	No peaks other than those present in blank	No peaks other than those present in blank

TABLE 4-21. C₁ - C₆ HYDROCARBON ANALYSES^a

Component	Retention Time (min)	Result (ppm-dry) ^b
Methane	--	5.4
Unknown	1.5	4.4
Unknown	2.0	3.1
Propane	--	11.7
Unknown	4.8	7.6
Unknown	6.5	11.1
Unknown	13.0	15.7
Unknown	15.5	38.3
Total		97.3

^aData not available for Low NO_x test

^bReported as ppm methane, dry basis

4.7.5 Summary of Organic Analysis

Organic emissions were generally higher in the flyash during the Baseline test and higher in the bottom ash during the Low NO_x test. These results are consistent with the measurements of unburned combustible material in the ash samples. Analysis of the boiler outlet SASS train samples showed higher flyash organic emissions during the Low NO_x test. Most of this would be reinjected into the furnace for better combustion efficiency however. Flue gas organic material was higher at both the boiler outlet and the ESP outlet for the Low NO_x test. The infrared spectra shows that the principal organic compound groups did not change significantly with the high overfire air firing arrangement. The level of flue gas organic emissions, however, increased significantly.

SECTION 5

SUMMARY

This test program conducted on a coal-fired travelling grate spreader stoker industrial boiler investigated changes in unit operation and multimedia emissions resulting from NO_x control implementation. In this program the effects of increased overfire air (OFA -- Low NO_x condition) were compared to emissions under normal operating conditions (Baseline condition). Summaries of the effects on boiler operation and emissions are given below.

Operation

Increased OFA (Low NO_x condition) caused apparent operating efficiency to increase from 77.8 percent to 80.8 percent. The largest contributing factor to the increase in efficiency was the decrease of combustible material in the flyash.

The percent of combustible material in the bottom ash increased by about 1.5 percent during Low NO_x firing. Low NO_x firing resulted in a decrease of 20 percent in combustible material found in the mechanical collector hopper. The combustion modification NO_x controls employed in this test program did not appear to cause any operating problems during the test program. There were no problems maintaining steam output. No excessive slagging of the furnace was noted. It must be noted, however, that these tests were of five to six hours duration. The long term effects of continuous operation under Low NO_x firing modes were not evaluated..

Gaseous Emissions

The boiler emissions of NO_x were decreased by about 10 percent during Low NO_x firing. Emission of CO were unaffected. At the outlet of the boiler, SO₂ emissions increased. The SO₃/SO₂ ratio was not significantly affected. The increase in SO₂ emissions during the Low NO_x test is most likely not due to changes in firing conditions. It was most likely caused by inhomogeneities in the coal composition or SO₂ measuring difficulties.

Particulate Emissions

Particulate loading at the boiler outlet during Low NO_x firing decreased to about 55 percent of the Baseline value. During Low NO_x firing, the particulate loading at the ESP outlet increased to 167 percent of the Baseline value. The collection efficiency of the air heater collector, mechanical collector and ESP was 99.85 percent in the Baseline test and 99.57 percent in the Low NO_x test.

At the boiler outlet about 76 percent of the particulate was greater than 10 μm during Baseline firing versus 90 percent in the Low NO_x test.

At the ESP outlet, the size distribution of particulates was similar. However, Baseline particulate material was slightly finer with about 18 percent being larger than 10 μm. In the Low NO_x test, about 25 percent was greater than 10 μm.

Trace Element Emissions

Low NO_x firing caused little, if any, change in trace element partitioning at the ESP hopper. However, this firing method enhanced the concentration of certain species in the bottom ash. No effect was noticed in size partitioning tendencies.

Low NO_x firing did increase the ESP outlet emissions of some trace elements. This increase in emissions is thought to be due to increased emissions of particulate at the outlet of the ESP. Increased emissions were found for, chromium, iron and titanium. The emissions of beryllium, boron and zinc were found to be lower during the Low NO_x test.

Organic Emissions

The emissions of flue gas vapor phase organic material was increased in the Low NO_x test. However ash stream organic emissions were generally decreased with the high overfire air flow used in the Low NO_x test. The infrared spectra of the organic extract showed that the types of organic compounds present were similar in each test.

REFERENCES

1. Mason H. B., et al., "Preliminary Environmental Assessment of Combustion Modification Techniques: Volume II, Technical Results," EPA-600/7-77-119b, Oct. 1977.
2. Gabrielson, J. E., Langsjoen, P. L., and Kosvic, T. C., "Field Tests of Industrial Stoker Coal-fired Boilers for Emissions Control and Efficiency Improvement -- Site A," EPA-600/7-78-136a, July 1978.
3. Hammersma, J. W., et al., "IERL-RTP Procedures Manual: Level 1 Environmental Assessment," EPA-600/2-76-160a, June 1976.
4. "Performance Test Code for Steam Generating Units," PTC 4.1, American Society of Mechanical Engineers, 1965.
5. Lentzen, D. E., et al., "IERL-RTP Procedures Manual: Level 1 Environmental Assessment (Second Edition)," EPA-600/7-78-201, October 1978.
6. "IERL-CRB Analysis Manual for Level 1 Assessment," ADL-783467-10-2, Author D. Little, Inc., Cambridge, MA, February 1977.
7. Blake, D. E., "Source Assessment Sampling System: Design and Development," EPA-600/7-78-018, Jan. 1977.

APPENDIX A
OPERATING DATA AND EFFICIENCY
TEST RESULTS

DATE	TEST	TIME	10/29/77	11/6/77	11/13/77	11/20/77	11/27/77	12/04/77	12/11/77	12/18/77	12/25/77	1/01/78	1/08/78	1/15/78	1/22/78	1/29/78	2/05/78	2/12/78	2/19/78	2/26/78	3/05/78	3/12/78	3/19/78	3/26/78	4/02/78	4/09/78	4/16/78	4/23/78	4/30/78	5/07/78	5/14/78	5/21/78	5/28/78	6/04/78	6/11/78	6/18/78	6/25/78	7/02/78	7/09/78	7/16/78	7/23/78	7/30/78	8/06/78	8/13/78	8/20/78	8/27/78	9/03/78	9/10/78	9/17/78	9/24/78	10/01/78	10/08/78	10/15/78	10/22/78	10/29/78	11/05/78	11/12/78	11/19/78	11/26/78	12/03/78	12/10/78	12/17/78	12/24/78	12/31/78	1/07/79	1/14/79	1/21/79	1/28/79	2/04/79	2/11/79	2/18/79	2/25/79	3/04/79	3/11/79	3/18/79	3/25/79	4/01/79	4/08/79	4/15/79	4/22/79	4/29/79	5/06/79	5/13/79	5/20/79	5/27/79	6/03/79	6/10/79	6/17/79	6/24/79	7/01/79	7/08/79	7/15/79	7/22/79	7/29/79	8/05/79	8/12/79	8/19/79	8/26/79	9/02/79	9/09/79	9/16/79	9/23/79	9/30/79	10/07/79	10/14/79	10/21/79	10/28/79	11/04/79	11/11/79	11/18/79	11/25/79	12/02/79	12/09/79	12/16/79	12/23/79	12/30/79	1/06/80	1/13/80	1/20/80	1/27/80	2/03/80	2/10/80	2/17/80	2/24/80	3/02/80	3/09/80	3/16/80	3/23/80	3/30/80	4/06/80	4/13/80	4/20/80	4/27/80	5/04/80	5/11/80	5/18/80	5/25/80	6/01/80	6/08/80	6/15/80	6/22/80	6/29/80	7/06/80	7/13/80	7/20/80	7/27/80	8/03/80	8/10/80	8/17/80	8/24/80	8/31/80	9/07/80	9/14/80	9/21/80	9/28/80	10/05/80	10/12/80	10/19/80	10/26/80	11/02/80	11/09/80	11/16/80	11/23/80	11/30/80	12/07/80	12/14/80	12/21/80	12/28/80	1/04/81	1/11/81	1/18/81	1/25/81	2/01/81	2/08/81	2/15/81	2/22/81	2/29/81	3/06/81	3/13/81	3/20/81	3/27/81	4/03/81	4/10/81	4/17/81	4/24/81	5/01/81	5/08/81	5/15/81	5/22/81	5/29/81	6/05/81	6/12/81	6/19/81	6/26/81	7/03/81	7/10/81	7/17/81	7/24/81	7/31/81	8/07/81	8/14/81	8/21/81	8/28/81	9/04/81	9/11/81	9/18/81	9/25/81	10/02/81	10/09/81	10/16/81	10/23/81	10/30/81	11/06/81	11/13/81	11/20/81	11/27/81	12/04/81	12/11/81	12/18/81	12/25/81	1/01/82	1/08/82	1/15/82	1/22/82	1/29/82	2/05/82	2/12/82	2/19/82	2/26/82	3/05/82	3/12/82	3/19/82	3/26/82	4/02/82	4/09/82	4/16/82	4/23/82	4/30/82	5/07/82	5/14/82	5/21/82	5/28/82	6/04/82	6/11/82	6/18/82	6/25/82	7/02/82	7/09/82	7/16/82	7/23/82	7/30/82	8/06/82	8/13/82	8/20/82	8/27/82	9/03/82	9/10/82	9/17/82	9/24/82	10/01/82	10/08/82	10/15/82	10/22/82	10/29/82	11/05/82	11/12/82	11/19/82	11/26/82	12/03/82	12/10/82	12/17/82	12/24/82	12/31/82	1/07/83	1/14/83	1/21/83	1/28/83	2/04/83	2/11/83	2/18/83	2/25/83	3/04/83	3/11/83	3/18/83	3/25/83	4/01/83	4/08/83	4/15/83	4/22/83	4/29/83	5/06/83	5/13/83	5/20/83	5/27/83	6/03/83	6/10/83	6/17/83	6/24/83	7/01/83	7/08/83	7/15/83	7/22/83	7/29/83	8/05/83	8/12/83	8/19/83	8/26/83	9/02/83	9/09/83	9/16/83	9/23/83	9/30/83	10/07/83	10/14/83	10/21/83	10/28/83	11/04/83	11/11/83	11/18/83	11/25/83	12/02/83	12/09/83	12/16/83	12/23/83	12/30/83	1/06/84	1/13/84	1/20/84	1/27/84	2/03/84	2/10/84	2/17/84	2/24/84	3/02/84	3/09/84	3/16/84	3/23/84	3/30/84	4/06/84	4/13/84	4/20/84	4/27/84	5/04/84	5/11/84	5/18/84	5/25/84	6/01/84	6/08/84	6/15/84	6/22/84	6/29/84	7/06/84	7/13/84	7/20/84	7/27/84	8/03/84	8/10/84	8/17/84	8/24/84	8/31/84	9/07/84	9/14/84	9/21/84	9/28/84	10/05/84	10/12/84	10/19/84	10/26/84	11/02/84	11/09/84	11/16/84	11/23/84	11/30/84	12/07/84	12/14/84	12/21/84	12/28/84	1/04/85	1/11/85	1/18/85	1/25/85	2/01/85	2/08/85	2/15/85	2/22/85	2/29/85	3/06/85	3/13/85	3/20/85	3/27/85	4/03/85	4/10/85	4/17/85	4/24/85	5/01/85	5/08/85	5/15/85	5/22/85	5/29/85	6/05/85	6/12/85	6/19/85	6/26/85	7/03/85	7/10/85	7/17/85	7/24/85	7/31/85	8/07/85	8/14/85	8/21/85	8/28/85	9/04/85	9/11/85	9/18/85	9/25/85	10/02/85	10/09/85	10/16/85	10/23/85	10/30/85	11/06/85	11/13/85	11/20/85	11/27/85	12/04/85	12/11/85	12/18/85	12/25/85	1/01/86	1/08/86	1/15/86	1/22/86	1/29/86	2/05/86	2/12/86	2/19/86	2/26/86	3/05/86	3/12/86	3/19/86	3/26/86	4/02/86	4/09/86	4/16/86	4/23/86	4/30/86	5/07/86	5/14/86	5/21/86	5/28/86	6/04/86	6/11/86	6/18/86	6/25/86	7/02/86	7/09/86	7/16/86	7/23/86	7/30/86	8/06/86	8/13/86	8/20/86	8/27/86	9/03/86	9/10/86	9/17/86	9/24/86	10/01/86	10/08/86	10/15/86	10/22/86	10/29/86	11/05/86	11/12/86	11/19/86	11/26/86	12/03/86	12/10/86	12/17/86	12/24/86	12/31/86	1/07/87	1/14/87	1/21/87	1/28/87	2/04/87	2/11/87	2/18/87	2/25/87	3/04/87	3/11/87	3/18/87	3/25/87	4/01/87	4/08/87	4/15/87	4/22/87	4/29/87	5/06/87	5/13/87	5/20/87	5/27/87	6/03/87	6/10/87	6/17/87	6/24/87	7/01/87	7/08/87	7/15/87	7/22/87	7/29/87	8/05/87	8/12/87	8/19/87	8/26/87	9/02/87	9/09/87	9/16/87	9/23/87	9/30/87	10/07/87	10/14/87	10/21/87	10/28/87	11/04/87	11/11/87	11/18/87	11/25/87	12/02/87	12/09/87	12/16/87	12/23/87	12/30/87	1/06/88	1/13/88	1/20/88	1/27/88	2/03/88	2/10/88	2/17/88	2/24/88	3/02/88	3/09/88	3/16/88	3/23/88	3/30/88	4/06/88	4/13/88	4/20/88	4/27/88	5/04/88	5/11/88	5/18/88	5/25/88	6/01/88	6/08/88	6/15/88	6/22/88	6/29/88	7/06/88	7/13/88	7/20/88	7/27/88	8/03/88	8/10/88	8/17/88	8/24/88	8/31/88	9/07/88	9/14/88	9/21/88	9/28/88	10/05/88	10/12/88	10/19/88	10/26/88	11/02/88	11/09/88	11/16/88	11/23/88	11/30/88	12/07/88	12/14/88	12/21/88	12/28/88	1/04/89	1/11/89	1/18/89	1/25/89	2/01/89	2/08/89	2/15/89	2/22/89	2/29/89	3/06/89	3/13/89	3/20/89	3/27/89	4/03/89	4/10/89	4/17/89	4/24/89	5/01/89	5/08/89	5/15/89	5/22/89	5/29/89	6/05/89	6/12/89	6/19/89	6/26/89	7/03/89	7/10/89	7/17/89	7/24/89	7/31/89	8/07/89	8/14/89	8/21/89	8/28/89	9/04/89	9/11/89	9/18/89	9/25/89	10/02/89	10/09/89	10/16/89	10/23/89	10/30/89	11/06/89	11/13/89	11/20/89	11/27/89	12/04/89	12/11/89	12/18/89	12/25/89	1/01/90	1/08/90	1/15/90	1/22/90	1/29/90	2/05/90	2/12/90	2/19/90	2/26/90	3/05/90	3/12/90	3/19/90	3/26/90	4/02/90	4/09/90	4/16/90	4/23/90	4/30/90	5/07/90	5/14/90	5/21/90	5/28/90	6/04/90	6/11/90	6/18/90	6/25/90	7/02/90	7/09/90	7/16/90	7/23/90	7/30/90	8/06/90	8/13/90	8/20/90	8/27/90	9/03/90	9/10/90	9/17/90	9/24/90	10/01/90	10/08/90	10/15/90	10/22/90	10/29/90	11/05/90	11/12/90	11/19/90	11/26/90	12/03/90	12/10/90	12/17/90	12/24/90	12/31/90	1/07/91	1/14/91	1/21/91	1/28/91	2/04/91	2/11/91	2/18/91	2/25/91	3/04/91	3/11/91	3/18/91	3/25/91	4/01/91	4/08/91	4/15/91	4/22/91	4/29/91	5/06/91	5/13/91	5/20/91	5/27/91	6/03/91	6/10/91	6/17/91	6/24/91	7/01/91	7/08/91	7/15/91	7/22/91	7/29/91	8/05/91	8/12/91	8/19/91	8/26/91	9/02/91	9/09/91	9/16/91	9/23/91	9/30/91	10/07/91	10/14/91	10/21/91	10/28/91	11/04/91	11/11/91	11/18/91	11/25/91	12/02/91	12/09/91	12/16/91	12/23/91	12/30/91	1/06/92	1/13/92	1/20/92	1/27/92	2/03/92	2/10/92	2/17/92	2/24/92	3/02/92	3/09/92	3/16/92	3/23/92	3/30/92	4/06/92	4/13/92	4/20/92	4/27/92	5/04/92	5/11/92	5/18/92	5/25/92	6/01/92	6/08/92	6/15/92	6/22/92	6/29/92	7/06/92	7/13/92	7/20/92	7/27/92	8/03/92	8/10/92	8/17/92	8/24/92	8/31/92	9/07/92	9/14/92	9/21/92	9/28/92	10/05/92	10/12/92	10/19/92	10/26/92	11/02/92	11/09/92	11/16/92	11/23/92	11/30/92	12/07/92	12/14/92	12/21/92	12/28/92	1/04/93	1/11/93	1/18/93	1/25/93	2/01/93	2/08/93	2/15/93	2/22/93	2/29/93	3/06/93	3/13/93	3/20/93	3/27/93	4/03/93	4/10/93	4/17/93	4/24/93	5/01/93	5/08/93	5/15/93	5/22/93	5/29/93	6/05/93	6/12/93	6/19/93	6/26/93	7/03/93	7/10/93	7/17/93	7/24/93	7/31/93	8/07/93	8/14/93	8/21/93	8/28/93	9/04/93	9/11/93	9/18/93	9/25/93	10/02/93	10/09/93	10/16/93	10/23/93	10/30/93	11/06/93	11/13/93	11/20/93	11/27/93	12/04/93	12/11/93	12/18/93	12/25/93	1/01/94	1/08/94	1/15/94	1/22/94	1/29/94	2/05/94	2/12/94	2/19/94	2/26/94	3/05/94	3/12/94	3/19/94	3/26/94	4/02/94	4/09/94	4/16/94	4/23/94	4/30/94	5/07/94	5/14/94	5/21/94	5/28/94	6/04/94	6/11/94	6/18/94	6/25/94	7/02/94	7/09/94	7/16/94	7/23/94	7/30/94	8/06/94	8/13/94	8/20/94	8/27/94	9/03/94	9/10/94	9/17/94	9/24/94	10/01/94	10/08/94	10/15/94	10/22/94	10/29/94	11/05/94	11/12/94	11/19/94	11/26/94	12/03/94	12/10/94	12/17/94	12/24/94	12/31/94	1/07/95	1/14/95	1/21/95	1/28/95	2/04/95	2/11/95	2/18/95	2/25/95	3/04/95	3/11/95	3/18/95	3/25/95	4/01/95	4/08/95	4/15/95	4/22/95	4/29/95	5/06/95	5/13/95	5/20/95	5/27/95	6/03/95	6/10/95	6/17/95	6/24/95	7/01/95	7/08/95	7/15/95	7/22/95	7/29/95	8/05/95	8/12/95	8/19/95	8/26/95	9/02/95	9/09/95	9/16/95	9/23/95	9/30/95	10/07/95	10/14/95	10/21/95	10/28/95	11/04/95	11/11/95	11/18/95	11/25/95	12/02/95	12/09/95	12/16/95	12/23/95	12/30/95	1/06/96	1/13/96	1/20/96	1/27/96	2/03/96	2/10/96	2/17/96	2/24/96	3/02/96	3/09/96	3/16/96	3/23/96	3/30/96	4/06/96	4/13/96	4/20/96	4/27/96	5/04/96	5/11/96	5/18/96	5/25/96	6/01/96	6/08/96	6/15/96	6/22/96	6/29/96	7/06/96	7/13/96	7/20/96	7/27/96	8/03/96	8/10/96	8/17/96	8/24/96	8/31/96	9/07/96	9/14/96	9/21/96	9/28/96	10/05/96	10/12/96	10/19/96	10/26/96	11/02/96	11/09/96	11/16/96	11/23/96	11/30/96	12/07/96	12/14/96	12/21/96	12/28/96	1/04/97	1/11/97	1/18/97	1/25/97
------	------	------	----------	---------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	---------	---------	---------	---------

DATE 10/29/77
 TEST HBA OFA
 TIME 1103 1140 1210 1255 1323 1355 1448 1510 1557 1646 1711

GAS DUCT TEMP OF INDICATOR	361	375	365	370	370	370	380	385	373	370
2D TEMP TO SCRUBBER FLOW	375	380	378	380	382	381	380	387	387	380
2D TEMP TO SCRUBBER W/20 W/20	510	513	512	514	512	514	514	516	510	512
SCRUBBER TEMP OF INDICATOR	120	120	120	120	120	120	120	118	121	120
SCRUBBER OFF GAS TEMP OF INDICATOR	140	135	138	135	135	132	133	128	137	135
POWER MAGNET ON	68	68	68	68	68	68	70	67	66	67
STEEL SPEED TO CONVEYOR	66	66	66	66	66	67	67	65	64	65
AIR FLOW % CENTRAL	45	50	50	51	52	52	53	55	63	51
FUELSIDE DRAFT % CENTRAL	26	30	29	31	32	32	33	37	42	32
FRESHWATER FLOW % CENTRAL	49	50	50	52	50	50	51	53	51	47
OFA PETS IN H2O	107	108	107	106	105	105	106	106	105	106
FRONT-TO-TOP, SAGE	105	105	105	104	105	104	104	103	108	104
REAR-TO-TOP, SAGE	105	103	103	104	103	103	103	105	100	103
REAR-TO-TOP, SAGE	107	107	106	106	107	105	104	105	107	105
ELIMINATOR (MECH. COLLECTOR) %	10	10	10	10	10	10	10	10	10	10
ELIMINATOR PRESSURE IN H2O	65	60	55	52	52	53	53	50	52	53
MECHANICAL COLLECTOR %	608	603	600	600	600	600	600	600	600	600
AIR HEATER %	70	80	75	75	75	80	80	80	80	80
BOILER GAGE										

COMMENTS: PRECIPITATOR FIELDS A, B, & D NOT OPERATING
 INCREASED AIR FLOW @ 1255 BECAUSE GRATE STARTED TO CLINKER UP

DATE	TEST	TIME	10/30/77	NORMAL OPERATION	1240	1300	1338	1400	1445	1530	1600	1630	1700	1730
STM HDR. PRES. (PSIG), GAGE			302	301	301	301	301	301	301	301	301	301	302	301
STM. FLOW (0-300000 $\frac{lb}{hr}$) % CHART			81	76	78	76	78	76	78	82	81	79	78	77
FDWTR. FLOW (0-400000 $\frac{lb}{hr}$) % CHART			59	56	55	54	59	54	59	60	59	59	57	57
DRUM LEVEL (0-40") % CHART			38	39	39	39	38	39	38	39	39	38	40	39
DRUM LEVEL IN. $\pm$ 1, LIGHTS			0	0	+1	+1	0	+1	0	+1	+1	0	+1	+1
STEAM FLOW INTEGRATOR (x3000 lb)			387073			387172					387320	387361	387398	387437
TIME OF INTEGRATOR READING			1240			1401					1557	1628	1657	1729
COAL AIR FLOW %, CHART			94	92	91	91	91	91	91	90	90	90	90	91
FD FAN PRES. IN. H_2O , GAGE			5.9	6.0	6.0	6.0	6.0	6.0	6.1	6.2	6.2	6.0	6.0	6.1
WINDBOX PRES. IN. H_2O , GAGE			0.3	0.4	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4
FURNACE PRES. IN. H_2O , GAGE			-0.25	-0.2	-0.2	-0.2	-0.15	-0.1	-0.15	-0.1	-0.1	-0.15	-0.15	-0.2
BOILER OUTLET PRES. IN. H_2O , GAGE			-0.7	-0.6	-0.7	-0.65	-0.55	-0.5	-0.55	-0.5	-0.55	-0.6	-0.65	-0.65
GRATE TEMP. OF TC#1			321	319	344	361	335	342	342	351	357	326	347	358
TC#2			337	334	351	345	354	349	349	357	357	377	383	397
TC#3			331	329	328	326	328	334	329	334	327	338	343	365
TC#4			332	329	331	331	331	332	331	332	328	334	333	349
TC#5			337	333	334	332	338	341	338	341	336	334	345	362
TC#6			340	340	333	337	350	366	350	366	344	345	360	411
BOILER OUTLET GAS TEMP. $^{\circ}$ F, TC#7			681	675	675	672	674	672	674	677	676	671	672	671
AIR INTR. OUTLET GAS TEMP. $^{\circ}$ F, TC#8			492	492	492	490	493	490	493	490	489	491	491	490
FURNACE AIR TEMP. $^{\circ}$ F, TC#9			347	342	341	340	343	340	343	340	340	343	343	341
FDWTR. TEMP. $^{\circ}$ F, TC#10			270	272	272	272	269	269	269	269	269	270	271	270

DATE	10/30/77												
TEST	NORMAL OPERATION												
TIME	1240	1300	1330	1400	1445	1530	1600	1630	1700	1730			
GAS OUTLET TEMP OF INDICATOR	392	390	390	397	388	388	387	387	386	385			
INLET TEMP TO SCRUBBER, INLET	400	400	400	400	397	398	398	398	398	398			
INLET TEMP TO SCRUBBER, INLET	605	605	605	606	606	606	605	605	605	606			
SCRUBBER TEMP OF INDICATOR	120	120	120	120	120	120	120	120	120	120			
SCRUBBER OFFGAS TEMP OF INDICATOR	130	130	130	130	130	130	130	130	130	125			
BOILER MASTER ON/OFF	40	40	42	45	46	46	47	48	50	50			
STEAMER SPEED TO CONTROL	40	38	40	43	45	45	45	46	47	47			
CHILLER FLOW TO CONTROL	72	72	71	72	72	72	72	72	72	82			
FURNACE DRAFT TO CONTROL	42	43	43	43	43	43	42	42	43	42			
FEEDWATER FLOW TO CONTROL	48	47	50	49	51	52	52	55	45	45			
CFA PRES. IN. H ₂ O	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8			
FRONT-TOP GAGE	5.2	5.3	5.2	5.1	5.2	5.2	5.2	5.1	5.2	5.2			
REAR-TOP GAGE	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0			
REAR-BOT GAGE	5.0	5.1	5.0	5.0	5.1	5.2	5.0	5.0	5.0	5.0			
FLASH REJECTION (MECH. COLLECTOR) YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO			
MECHANICAL CELL TO GAGE	8.0	8.0	8.2	7.8	8.0	8.2	8.2	7.8	7.5	8.2			
AIR FLOW TO GAGE	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.2			
BOILER GAGE	8.8	9.0	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5			

COMMENTS: PRECIPITATOR FIELDS A, B, & D NOT OPERATING

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

TEST NO. 34

BOILER NO.

DATE 10/29/79

OWNER OF PLANT

LOCATION

TEST CONDUCTED BY

OBJECTIVE OF TEST Low NO_x

DURATION

FIRER MAKE & TYPE

RATED CAPACITY

FIRER TYPE & SIZE

PULVERIZER, TYPE & SIZE

BURNER, TYPE & SIZE

FUEL USED

MINE

COUNTY

STATE

SIZE AS FIRED

PRESSURES & TEMPERATURES

FUEL DATA

1	STEAM PRESSURE IN BOILER DRUM	psia		COAL AS FIRED PROX. ANALYSIS	% wt		OIL
2	STEAM PRESSURE AT S. H. OUTLET	psia		37	MOISTURE	14.58	51 FLASH POINT F*
3	STEAM PRESSURE AT R. H. INLET	psia		38	VOL MATTER	34.43	52 Sp. Gravity Deg. API*
4	STEAM PRESSURE AT R. H. OUTLET	psia		39	FIXED CARBON		53 VISCOSITY AT SSU* BURNER SSF
5	STEAM TEMPERATURE AT S. H. OUTLET	F		40	ASH	7.88	44 TOTAL HYDROGEN % wt
6	STEAM TEMPERATURE AT R. H. INLET	F			TOTAL		41 Btu per lb
7	STEAM TEMPERATURE AT R. H. OUTLET	F		41	Btu per lb AS FIRED	10300	(constant pressure)
8	WATER TEMP. ENTERING (ECON.) (BOILER)	F		42	ASH SOFT TEMP.* ASTM METHOD		GAS % VOL
9	STEAM QUALITY % MOISTURE OR P. P. M.				COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54 CO
10	AIR TEMP. AROUND BOILER (AMBIENT)	F		43	CARBON	60.06	55 CH ₄ METHANE
11	TEMP. AIR FOR COMBUSTION (This is Reference Temperature) †	F	59	44	HYDROGEN	4.12	56 C ₂ H ₂ ACETYLENE
12	TEMPERATURE OF FUEL	F		45	OXYGEN	12.05	57 C ₂ H ₄ ETHYLENE
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	372	46	NITROGEN	9.95	58 C ₂ H ₆ ETHANE
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F		47	SULPHUR	0.36	59 H ₂ S
				48	ASH	7.88	60 CO ₂
				37	MOISTURE	14.58	61 H ₂ HYDROGEN

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb		37	MOISTURE	14.58	61	H ₂	HYDROGEN
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb			TOTAL			TOTAL	
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb			COAL PULVERIZATION			TOTAL HYDROGEN % wt	
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb		48	GRINDABILITY INDEX*		62	DENSITY 68 F ATM. PRESS.	
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb		49	FINENESS % THRU 50 M*		63	Btu PER CU FT	
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb		50	FINENESS % THRU 200 M*		41	Btu PER LB	
21	HEAT ABS/LB R. H. STEAM (ITEM 19 - ITEM 18)	Btu/lb		64	INPUT-OUTPUT EFFICIENCY OF UNIT %		ITEM 31 × 100 ITEM 29		
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	0.0693		HEAT LOSS EFFICIENCY		Btu/lb A. F. FUEL	% of A. F. FUEL	
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	3418	65	HEAT LOSS DUE TO DRY GAS		853	8.28	
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.584	66	HEAT LOSS DUE TO MOISTURE IN FUEL		175	1.70	
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	11.35	67	HEAT LOSS DUE TO H ₂ O FROM COMB. OF H ₂		446	4.33	
				68	HEAT LOSS DUE TO COMBUST. IN REFUSE		237	2.30	
26	ACTUAL WATER EVAPORATED	lb/hr		69	HEAT LOSS DUE TO RADIATION			1.14	
27	REHEAT STEAM FLOW	lb/hr		70	UNMEASURED LOSSES			1.50	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr		71	TOTAL			19.25	
29	TOTAL HEAT INPUT (Item 28 × Item 41) 1000	kB/hr		72	EFFICIENCY = (100 - Item 71)			80.75	
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr							
31	TOTAL HEAT OUTPUT (Item 26 × Item 20) + (Item 27 × Item 21) + Item 30 1000	kB/hr							

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO ₂	% VOL	13.0
33	O ₂	% VOL	5.9
34	CO	% VOL	0.03
35	N ₂ (BY DIFFERENCE)	% VOL	81.07
36	EXCESS AIR	%	39

* Not Required for Efficiency Testing

† For Point of Measurement See Per. 7.2.8.1-PTC 4.1-1964

CALCULATION SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-b (1964)

Revised September, 1965

OWNER OF PLANT		TEST NO. 34	BOILER NO.	DATE
30	HEAT OUTPUT IN BOILER BLOW-DOWN WATER = LB OF WATER BLOW-DOWN PER HR x		ITEM 15 1000	ITEM 17 = ... kB/hr
24	If impractical to weigh refuse, this item can be estimated as follows DRY REFUSE PER LB OF AS FIRED FUEL = $\frac{\% \text{ ASH IN AS FIRED COAL}}{100 - \% \text{ COMB. IN REFUSE SAMPLE}}$ CARBON BURNED PER LB AS FIRED FUEL = $\frac{\text{ITEM 43}}{100} - \left[\frac{\text{ITEM 22} \times \text{ITEM 23}}{14,500} \right] = 0.584$		NOTE: IF FLUE DUST & ASH PIT REFUSE DIFFER MATERIALLY IN COMBUSTIBLE CONTENT, THEY SHOULD BE ESTIMATED SEPARATELY. SEE SECTION 7, COMPUTATIONS.	
25	DRY GAS PER LB AS FIRED FUEL = $\frac{11\text{CO}_2 + 8\text{O}_2 + 7(\text{N}_2 + \text{CO})}{3(\text{CO}_2 + \text{CO})} \times (\text{LB CARBON BURNED PER LB AS FIRED FUEL} + \frac{3}{8} \text{S})$ = $11 \times \frac{\text{ITEM 32}}{13} + 8 \times \frac{\text{ITEM 33}}{5.9} + 7 \left(\frac{\text{ITEM 35}}{8.07} + \frac{\text{ITEM 34}}{0.03} \right) \times \left[\frac{\text{ITEM 24}}{0.584} + \frac{\text{ITEM 47}}{0.36} \right] = 11.35$ = $3 \times \left(\frac{\text{ITEM 32}}{13.0} + \frac{\text{ITEM 34}}{0.03} \right)$			
36	EXCESS AIR † = $100 \times \frac{\text{O}_2 - \frac{\text{CO}}{2}}{.2682\text{N}_2 - (\text{O}_2 - \frac{\text{CO}}{2})} = 100 \times \frac{\text{ITEM 33} - \frac{\text{ITEM 34}}{2}}{.2682(\text{ITEM 35}) - (\text{ITEM 33} - \frac{\text{ITEM 34}}{2})} = \dots\dots\dots$			
HEAT LOSS EFFICIENCY 11.4			Btu/lb AS FIRED FUEL	LOSS HHV 100 =
65	HEAT LOSS DUE TO DRY GAS = $\frac{\text{LB DRY GAS PER LB AS FIRED FUEL} \times C_p \times (t_{\text{vg}} - t_{\text{air}})}{\text{Unit}} = \frac{\text{ITEM 25}}{11.35} \times 0.24 \times (\text{ITEM 13}) - (\text{ITEM 11}) = 372.59 \dots\dots\dots$		853	$\frac{65}{41} \times 100 = 8.28$
66	HEAT LOSS DUE TO MOISTURE IN FUEL = $\frac{\text{LB H}_2\text{O PER LB AS FIRED FUEL} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T GAS LVG}) - (\text{ENTHALPY OF LIQUID AT T AIR})]}{100} = \frac{\text{ITEM 37}}{122.9} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T ITEM 13}) - (\text{ENTHALPY OF LIQUID AT T ITEM 11})] = \dots\dots\dots$		176	$\frac{66}{41} \times 100 = 1.70$
67	HEAT LOSS DUE TO H ₂ O FROM COMB. OF H ₂ = $9\text{H}_2 \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T GAS LVG}) - (\text{ENTHALPY OF LIQUID AT T AIR})] = 9 \times \frac{\text{ITEM 44}}{100} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T ITEM 13}) - (\text{ENTHALPY OF LIQUID AT T ITEM 11})] = \dots\dots\dots$		446	$\frac{67}{41} \times 100 = 4.33$
68	HEAT LOSS DUE TO COMBUSTIBLE IN REFUSE = $\text{ITEM 22} \times \text{ITEM 23} = 0.693 \times 3.418 = \dots\dots\dots$		237	$\frac{68}{41} \times 100 = 2.30$
69	HEAT LOSS DUE TO RADIATION* = $\frac{\text{TOTAL BTU RADIATION LOSS PER HR}}{\text{LB AS FIRED FUEL} - \text{ITEM 28}} = \dots\dots\dots$			$\frac{69}{41} \times 100 = 1.14$
70	UNMEASURED LOSSES **			$\frac{70}{41} \times 100 = 1.50$
71	TOTAL			19.25
72	EFFICIENCY = (100 - ITEM 71)			80.75

† For rigorous determination of excess air see Appendix 9.2 - PTC 4.1-1964

* If losses are not measured, use ABMA Standard Radiation Loss Chart, Fig. 8, PTC 4.1-1964

** Unmeasured losses listed in PTC 4.1 but not tabulated above may be provided for by assigning a mutually agreed upon value for Item 70.

SUMMARY SHEET

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

TEST NO. <u>3.5</u>		BOILER NO.	DATE <u>10/30/78</u>
OWNER OF PLANT		LOCATION	
TEST CONDUCTED BY		OBJECTIVE OF TEST <u>Baseline</u>	DURATION
FIRER MAKE & TYPE		RATED CAPACITY	
FIRER TYPE & SIZE		BURNER, TYPE & SIZE	
FUEL USED		MINE	COUNTY
		STATE	SIZE AS FIRED

PRESSURES & TEMPERATURES				FUEL DATA			
1	STEAM PRESSURE IN BOILER DRUM	psia		COAL AS FIRED PROX. ANALYSIS	% wt		OIL
2	STEAM PRESSURE AT S. H. OUTLET	psia		37	MOISTURE	13.76	51
3	STEAM PRESSURE AT R. H. INLET	psia		38	VOL MATTER	84.88	52
4	STEAM PRESSURE AT R. H. OUTLET	psia		39	FIXED CARBON		53
5	STEAM TEMPERATURE AT S. H. OUTLET	F		40	ASH	7.18	44
6	STEAM TEMPERATURE AT R. H. INLET	F			TOTAL		41
7	STEAM TEMPERATURE AT R. H. OUTLET	F		41	Btu per lb AS FIRED	10636	(10615 const vol)
8	WATER TEMP. ENTERING (ECON.) (BOILER)	F		42	ASH SOFT TEMP.* ASTM METHOD		
9	STEAM QUALITY % MOISTURE OR P. P. M.				COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54
10	AIR TEMP. AROUND BOILER (AMBIENT)	F		43	CARBON	60.87	55
11	TEMP. AIR FOR COMBUSTION (This is Reference Temperature) †	F	45	44	HYDROGEN	4.27	56
12	TEMPERATURE OF FUEL	F		45	OXYGEN	12.61	57
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	388	46	NITROGEN	0.97	58
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F		47	SULPHUR	0.34	59
				40	ASH	7.18	60
				37	MOISTURE	13.76	61
					TOTAL		TOTAL
					COAL PULVERIZATION		TOTAL HYDROGEN % wt
				48	GRINDABILITY INDEX*		62
				49	FINESS % THRU 50 M*		63
				50	FINESS % THRU 200 M*		41
				64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 x 100 ITEM 29	

UNIT QUANTITIES				FUEL DATA			
15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb		37	MOISTURE	13.76	61
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb			TOTAL		TOTAL
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb			COAL PULVERIZATION		TOTAL HYDROGEN % wt
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb		48	GRINDABILITY INDEX*		62
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb		49	FINESS % THRU 50 M*		63
20	HEAT ABS/LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb		50	FINESS % THRU 200 M*		41
21	HEAT ABS/LB R. H. STEAM (ITEM 19 - ITEM 18)	Btu/lb		64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 x 100 ITEM 29	
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	0.0896		HEAT LOSS EFFICIENCY		Btu/lb A. F. FUEL
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	5775	65	HEAT LOSS DUE TO DRY GAS		924
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	0.573	66	HEAT LOSS DUE TO MOISTURE IN FUEL		168
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb		67	HEAT LOSS DUE TO H ₂ O FROM COMB. OF H ₂		470
				68	HEAT LOSS DUE TO COMBUST. IN REFUSE		517
				69	HEAT LOSS DUE TO RADIATION		1.14
				70	UNMEASURED LOSSES		1.50
				71	TOTAL		22.20
				72	EFFICIENCY = (100 - Item 71)		77.80

HOURLY QUANTITIES				FUEL DATA			
26	ACTUAL WATER EVAPORATED	lb/hr		69	HEAT LOSS DUE TO RADIATION		1.14
27	REHEAT STEAM FLOW	lb/hr		70	UNMEASURED LOSSES		1.50
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr		71	TOTAL		22.20
29	TOTAL HEAT INPUT (Item 28 x Item 41) 1000	kB/hr		72	EFFICIENCY = (100 - Item 71)		77.80
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr					
31	TOTAL HEAT OUTPUT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 1000	kB/hr					

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET				FUEL DATA			
32	CO ₂	% VOL	12.9				
33	O ₂	% VOL	6				
34	CO	% VOL	0.03				
35	N ₂ (BY DIFFERENCE)	% VOL	81.07				
36	EXCESS AIR	%	38				

* Not Required for Efficiency Testing

† For Point of Measurement See Per. 7.2.8.1-PTC 4.1-1964

OWNER OF PLANT		TEST NO. 35	BOILER NO.	DATE 10/30/78
30	HEAT OUTPUT IN BOILER BLOW-DOWN WATER = LB OF WATER BLOW-DOWN PER HR x		$\frac{\text{ITEM 15} - \text{ITEM 17}}{1000}$	hB/hr
24	If impractical to weigh refuse, this item can be estimated as follows DRY REFUSE PER LB OF AS FIRED FUEL = $\frac{\% \text{ ASH IN AS FIRED COAL}}{100 - \% \text{ COMB. IN REFUSE SAMPLE}}$ CARBON BURNED PER LB AS FIRED FUEL = $\frac{\text{ITEM 43}}{100} - \frac{[\text{ITEM 22} \times \text{ITEM 23}]}{14,500} = 0.573$		NOTE: IF FLUE DUST & ASH PIT REFUSE DIFFER MATERIALLY IN COMBUSTIBLE CONTENT, THEY SHOULD BE ESTIMATED SEPARATELY. SEE SECTION 7, COMPUTATIONS.	
25	DRY GAS PER LB AS FIRED FUEL = $\frac{11\text{CO}_2 + 8\text{O}_2 + 7(\text{N}_2 + \text{CO})}{3(\text{CO}_2 + \text{CO})} \times (\text{LB CARBON BURNED PER LB AS FIRED FUEL} + \frac{3}{8} \text{ S})$ = $11 \times \frac{\text{ITEM 32}}{12.9} + 8 \times \frac{\text{ITEM 33}}{6.0} + 7 \times \frac{(\text{ITEM 35} + \text{ITEM 34})}{(81.07 + 0.03)} \times \left[\frac{\text{ITEM 24}}{0.573} + \frac{\text{ITEM 47}}{0.34} \right] = 11.22$ $3 \times \frac{(\text{ITEM 32} + \text{ITEM 34})}{(12.9 + 0.03)}$			
36	EXCESS AIR % = $100 \times \frac{\text{O}_2 - \frac{\text{CO}}{2}}{.2682\text{N}_2 - (\text{O}_2 - \frac{\text{CO}}{2})} = 100 \times \frac{\text{ITEM 33} - \frac{\text{ITEM 34}}{2}}{.2682(\text{ITEM 35}) - (\text{ITEM 33} - \frac{\text{ITEM 34}}{2})}$			
HEAT LOSS EFFICIENCY			Btu/lb AS FIRED FUEL	LOSS %
65	HEAT LOSS DUE TO DRY GAS = $\text{LB DRY GAS PER LB AS FIRED FUEL} \times C_p \times (t_{\text{vg}} - t_{\text{air}}) = \frac{\text{ITEM 25}}{11.22} \times 0.24 \times (\text{ITEM 13} - \text{ITEM 11}) = 388 - 45 = 343$		924	$\frac{65}{41} \times 100 = 8.69$
66	HEAT LOSS DUE TO MOISTURE IN FUEL = $\text{LB H}_2\text{O PER LB AS FIRED FUEL} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T GAS LVG}) - (\text{ENTHALPY OF LIQUID AT T AIR})] = \frac{\text{ITEM 37}}{100} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T ITEM 13}) - (\text{ENTHALPY OF LIQUID AT T ITEM 11})] = 1236 - 13.06 = 1222.94$		168	$\frac{66}{41} \times 100 = 1.58$
67	HEAT LOSS DUE TO H ₂ O FROM COMB. OF H ₂ = $9\text{H}_2 \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T GAS LVG}) - (\text{ENTHALPY OF LIQUID AT T AIR})] = 9 \times \frac{\text{ITEM 44}}{100} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA \& T ITEM 13}) - (\text{ENTHALPY OF LIQUID AT T ITEM 11})] = 470$		470	$\frac{67}{41} \times 100 = 4.42$
68	HEAT LOSS DUE TO COMBUSTIBLE IN REFUSE = $\text{ITEM 22} \times \text{ITEM 23} = 0.0896 \times 5.775 = 0.517$		517	$\frac{68}{41} \times 100 = 4.87$
69	HEAT LOSS DUE TO RADIATION* = $\frac{\text{TOTAL BTU RADIATION LOSS PER HR}}{\text{LB AS FIRED FUEL} - \text{ITEM 28}}$			$\frac{69}{41} \times 100 = 1.14$
70	UNMEASURED LOSSES**			$\frac{70}{41} \times 100 = 1.50$
71	TOTAL			23.20
72	EFFICIENCY = (100 - ITEM 71)			77.80

† For rigorous determination of excess air see Appendix 9.2 - PTC 4.1-1964

* If losses are not measured, use ABMA Standard Radiation Loss Chart, Fig. 8, PTC 4.1-1964

** Unmeasured losses listed in PTC 4.1 but not tabulated above may be provided for by assigning a mutually agreed upon value for Item 70.

BOILER DESIGN DATA*

Foster Wheeler Boiler

Design Steaming Capacity	300,000 lb/hr
Design Pressure	350 psi
Final Steam Temperature	427°F
Boiler Heating Surface	20,186 ft ²
Waterwall Heating Surface	2,982 ft ²
Economizer Heating Surface	13,276 ft ²
Furnace Volume	16,712 ft ³
Year Built	1976
Type	VOSP

Detroit Stoker

Number of feeders	7
Grate Type	Split, Continuous Front Discharge
Grate Length (shaft to shaft)	20'8"
Grate Width	27'1-1/2"
Effective Grate Area	515.4 ft ²
Recommended Coal Sizing	3/4"x0 with no more than 25% thru 1/4"
Grate Thermocouple Location	6 in air seal beams, 23-1/8" forward of rear grate shaft

Overfire Air

Upper Rear:	25 jets @ 12" spacing, 6'0" above grate, 9° below horizontal
Lower Rear:	27 jets @ 8-16" spacing, 2'2" above grate except end two which are 1'0" above grate, horizontal
Upper Front:	25 jets @ 12" spacing, 6'6" above grate, 19° below horizontal
Lower Front:	Underfeeder air located about 10" above grate
Discussion:	The OFA system is completely separate from the FD system. The overfire air is nonheated ambient air from inside the plant. Maximum obtainable OFA pressures are 12-15 in. H ₂ O.

Flyash Reinjection

Boiler Hopper:	6 injectors @ 4'0" and 4'4" spacings
Air Heater Hopper:	7 injectors @ 4'0" and 4'4" spacings
Mechanical Hopper:	12 injectors @ 2'0" and 2'4" spacings
Discussion:	Mechanical hopper ash can be stored in a surge hopper and discarded rather than reinjected at the boiler operators option.

*Extracted from Reference 2

BOILER DESIGN PERFORMANCE SUMMARY*

	<u>Max. Load</u>	<u>Base Load</u>
Steam Flow, 10 ³ lb/hr	300	250
Steam Temperature Boiler Outlet, °F	427	427
Pressure Boiler Drum, psig	320	320
Temp. Feedwater Entering Unit, °F	240	240
Temp. Feedwater Leaving Economizer, °F	313	291
Temp. Air Entering Unit, °F	80	80
Temp. Air Leaving Air Heater, °F	317	346
Temp. Gas Leaving Furnace, °F	1,960	--
Temp. Gas Leaving Boiler, °F	765	687
Temp. Gas Leaving Air Heater, °F	600	498
Temp. Gas Leaving Economizer, °F	350	310
Excess Air Leaving Furnace, %	25	25
Wet Gas Entering Air Heater, 10 ³ lb/hr	364	302
Wet Gas Leaving Air Heater, 10 ³ lb/hr	364	302
Air Entering Air Heater, 10 ³ lb/hr	326	271
Air Leaving Air Heater, 10 ³ lb/hr	326	271
Draft in Furnace, in. H ₂ O	- .2	- .2
Gas Side Loss Thru Boiler, in. H ₂ O	0.56	0.39
Gas Side Loss Thru Mechanical D.C., in. H ₂ O	2.50	1.72
Gas Side Loss Thru Air Heater, in. H ₂ O	2.90	2.00
Gas Side Loss Thru ESP, in. H ₂ O	0.64	0.44
Gas Side Loss Thru Economizer, in. H ₂ O	2.07	1.42
Gas Side Loss Thru Flues, in. H ₂ O	0.64	0.44
Air Side Loss Thru Air Heater, in. H ₂ O	2.74	1.89
Air Side Loss Thru Ducts, in. H ₂ O	0.76	0.53
Air Side Loss Thru Grate, in. H ₂ O	3.17	2.19
Air Side Loss Thru Steam Coil, in. H ₂ O	1.00	0.69
Air Side Loss Thru Air Measuring Device, in. H ₂ O	1.27	0.88
Fuel Flow, 10 ³ lb/hr	31,726	26,000
Liberation, BTU/hr/ft ³ total vol.	21,452	17,584
Dry Gas Loss, %	6.47	5.51
Hydrogen & Moisture in Fuel Loss, %	5.50	5.41
Moisture in Air Loss, %	0.11	0.09
Unburned Combustible Loss, %	1.70	1.41
Radiation Loss From Boiler, %	0.34	0.41
Radiation Loss From Precipitator, %	0.70	0.70
Manufacturers Margin, %	1.50	1.50
Unit Efficiency, %	83.68	84.97

*Extracted from Reference 2

ULTIMATE ANALYSIS OF COAL UPON WHICH PERFORMANCE DATA IS BASED*

Ash	2.67% (8% max.)
S	0.81% (1.5% max.)
H ₂	4.71%
C	64.83%
N ₂	1.08%
O ₂	14.90%
H ₂ O	11.00%
BTU/lb as Fired	11,300

*Extracted from Reference 2

APPENDIX B
ANALYTICAL PROCEDURES

Level 1 Organic Analysis Procedure Modification

Pilot Studies Protocol

Reasons for this Modification:

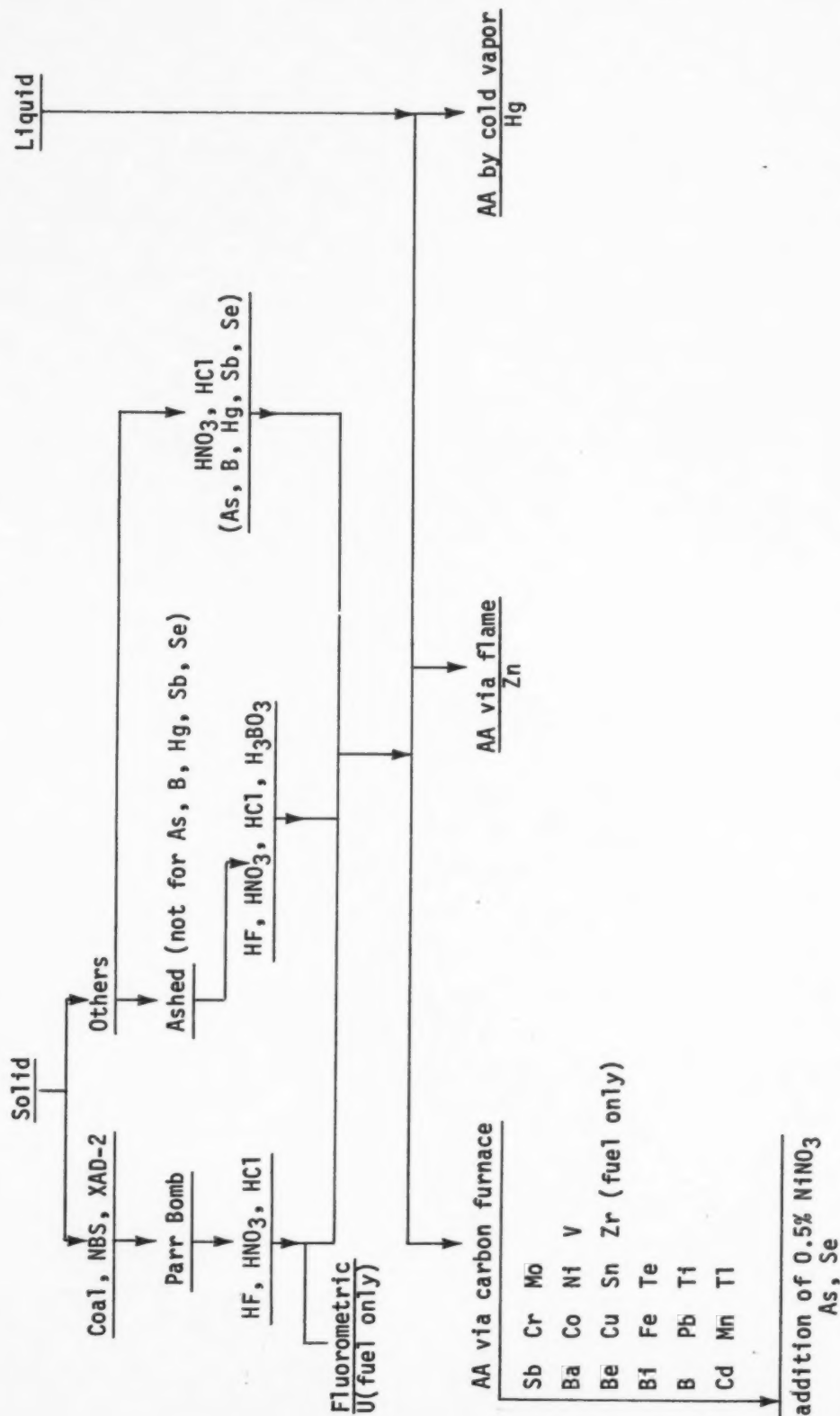
The original Level 1 Organic Analysis Procedure, as specified in the June 1976 Procedures Manual, was designed in a manner which provided qualitative compound class identification and quantitative (gravimetric) data for those components of a sample that are retained when an organic sample extract is evaporated to dryness. For more volatile sample components, only quantitative information (quantities of material in defined boiling point ranges) was to be obtained. It was implicitly assumed that all compounds with boiling points $\geq$ ca. 220°C (C_{13} and higher normal hydrocarbon range) would be retained and carried through the LC-IR-LRMS procedure, while those boiling below 220°C (C_{12} and lower normal hydrocarbons down to C_7^*) might be lost during sample evaporation to dryness.

New experimental data have shown that:

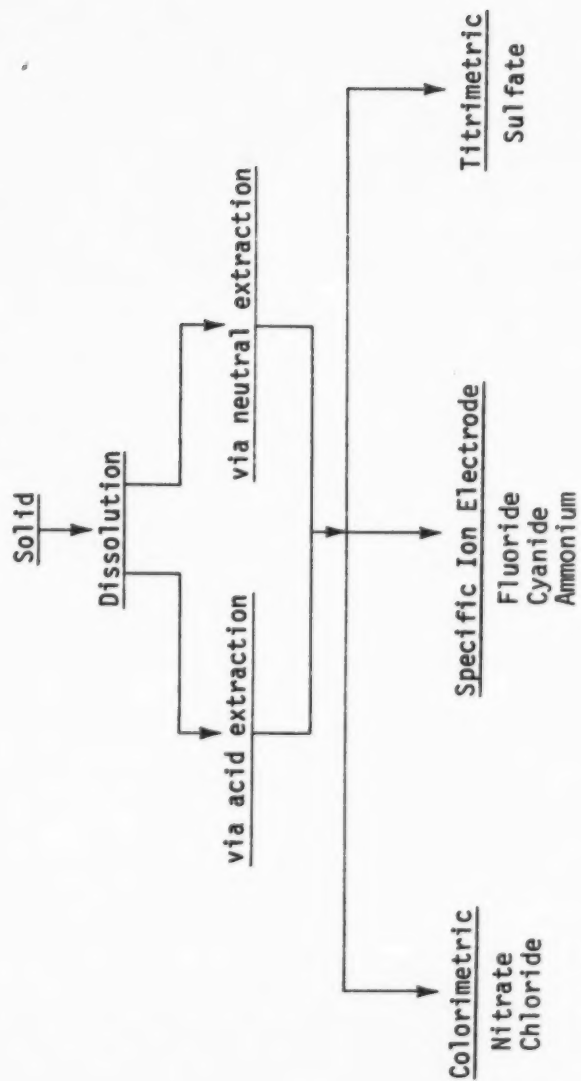
1. The range of material lost when the sample is evaporated to dryness for the gravimetric analysis and preparation of the LC sample is somewhat higher than anticipated: It is probably only C_{16} and higher (rather than C_{13} and higher) hydrocarbons that are retained. The C_{16} n-alkane boiling point is about 275°C .
2. Many of the compounds which are considered to be of concern in environmental assessment as a whole (not just Level 1) are in the boiling point range that would correspond to loss prior to LC,

* C_1 - C_6 are to be done by on-site GC.

ELEMENTAL ANALYSIS FLOW SHEET



ANIONS PLUS AMMONIUM ANALYSIS FLOW SHEET



according to present procedures. Thus, no compound class information would be available from Level 1 to indicate the possible presence or to confirm the absence of significant amounts of these materials.

A revised procedure for Level 1 has been devised and subjected to limited experimental validation. The principal feature of this procedure, compared to the original, is that the organic extract is not evaporated to dryness prior to LC and/or LRMS analyses. Two new sample handling steps are required:

- A quantitative assay procedure, TCO (total chromatographable organics) to complement the gravimetric analysis, and give quantitative data on C_7 - C_{16} range materials.
- A solvent exchange step to transfer the sample from CH_2Cl_2 extract to a non-polar solvent and allow lower boiling material ($>C_7$) to go through LC and subsequent steps.

A new flow diagram is shown in Figure 1. The two new procedures are described on the following pages.

The total mass data for extracted samples is now taken as the sum of the value determined from the TCO and gravimetric assay. (TCO + GRAV)

Note that the C_7 - C_{12} GC assay is now not required.

Both qualitative and quantitative data are expected to be obtained by this scheme for all materials boiling above the C_7 paraffin.

All other provisions, criteria and instruction of the Procedures Manual apply except for the noted changes.

TCO

Analyze a $1\ \mu\text{l}$ aliquot of solution by GC using a flame ionization detector. A 6 ft x 1/8 in. O.D. column of 10 percent OV-101 on 100/120

mesh Supelcoport has been used successfully for this analysis. Other silicon phases (OV-1, etc.) may work as well, but a 10 percent loading is recommended. The GC should be operated isothermally at about 30°C - or room temperature - for 5 minutes after sample injection and then programmed at approximately 20°C per minute to 250°C and held at 250°C as long as necessary for complete elution of sample.

Integrator should be set to begin integration at heptane (C₇) peak maxima and terminate at the peak maxima of the heptadecane (C₁₇) peak, as determined from calibration standards. In this manner the integrated area will cover material in the boiling range of C₇-C₁₆.

Calibration should be done with a mixture containing a homologous series of hydrocarbons from C₇ to C₁₆. Standards should be prepared to cover the concentration range to be studied.

Solvent Exchange:

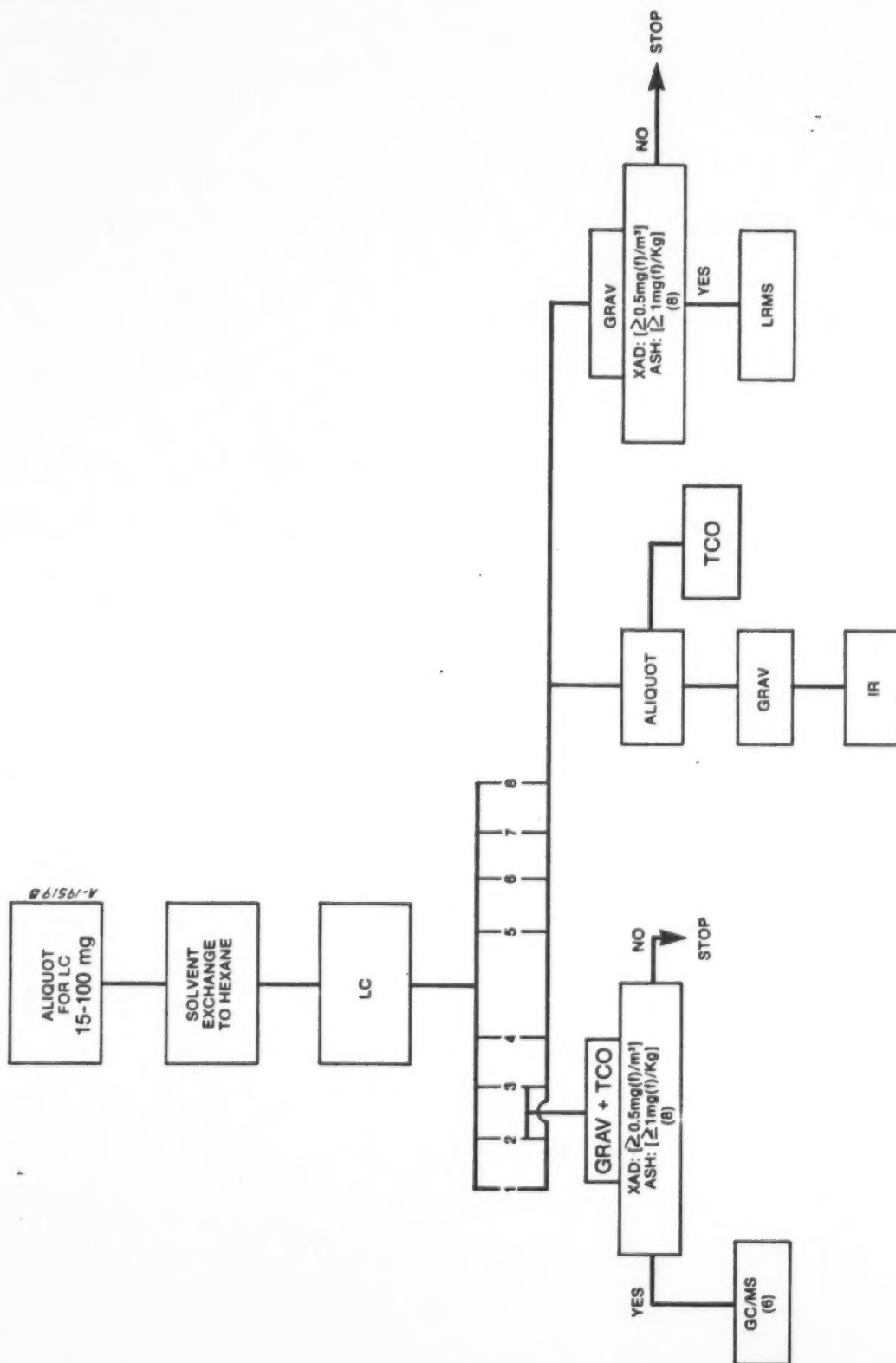
Place 1-5 ml of CH₂Cl₂ extract containing 15-100 mg of solute (TCO + GRAV), preferably 100 mg, in graduated centrifuge tube or K-D receiver. Add 200 mg of silica gel prepared as for the LC column. Evaporate if necessary to reduce volume to 1 ml.

Add 1 ml cyclopentane and mix by gentle agitation. Again reduce volume to 1 ml by evaporation.

Add 1 ml more of cyclopentane and mix. Reduce volume to 1 ml again.

Transfer cyclopentane and silica gel (a Pasteur pipette works well) to top of previously prepared LC column.

Run column as directed in Manual, rinsing graduated receiver with fresh solvents as they are introduced in the elution sequence.



SASS analysis procedure liquid chromatography

APPENDIX C
TRACE ELEMENT CONCENTRATIONS

Symbols appearing in the tables:

DSCM	Dry Standard Cubic Meter
ESP	Electrostatic Precipitator
KG	Kilogram
MCG	Microgram
MIN	Minute
PPM	Part per million by weight
<	Less than
*	Sample not analyzed for the particular element/or ionic specie
N	Sample not analyzed
-	Concentration in the sample is less than the concentration in the blank

SPREADER STOKER INDUSTRIAL BOILER FUEL INLET
TRACE ELEMENT CONCENTRATION - (PPM) -

TRACE ELEMENTS	TEST CONDITION	
	BASELINE	LOW NOX
CATIONS		
ANTIMONY	< .200	< .200
ARSENIC	< .200	< .200
BARIUM	135.	65.0
BERYLLIUM	.400	.200
BISMUTH	< 1.00	< 1.00
BORON	18.0	16.0
CADMIUM	< .100+00	< .100+00
CHROMIUM	2.30	2.20
COBALT	3.20	1.30
COPPER	6.70	5.30
IRON	.237+04	.286+04
LEAD	< 3.00	< 3.00
MANGANESE	49.0	58.0
MERCURY	.200-01	.200-01
MOLYBDENUM	< 3.00	< 3.00
NICKEL	.800	.700
SELENIUM	.200	.800
TELLURIUM	< .200	< .200
THALLIUM	< 2.00	< 2.00
TIN	.300	25.0
TITANIUM	860.	430.
URANIUM	.150	.110
VANADIUM	9.40	6.00
ZINC	5.70	5.30
ZIRCONIUM	14.0	36.0
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - BOTTOM ASH

TRACE ELEMENTS	TEST CONDITION	
	CATIONS	ANIONS
	BASELINE	LOW NOX
ANTIMONY	< .600	< .700
ARSENIC	2.00	3.00
BARIUM	240.	150.
BERYLLIUM	.800	1.30
BISMUTH	< 40.0	< 40.0
BORON	< 5.00	< 5.00
CADMIUM	< 1.00	< 1.00
CHROMIUM	24.0	26.0
COBALT	< 5.00	< 6.00
COPPER	42.0	35.0
IRON	.300+05	.310+05
LEAD	< 20.0	< 20.0
MANGANESE	540.	560.
MERCURY	* .000	* .000
MOLYBDENUM	< 1.00	< 2.00
NICKEL	6.00	7.00
SELENIUM	.400	2.10
TELLURIUM	< .800	< .900
THALLIUM	< 50.0	< 60.0
TIN	520.	390.
TITANIUM	.420+04	.400+04
URANIUM	* .000	* .000
VANADIUM	< 20.0	< 20.0
ZINC	17.0	19.0
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	< 32.9	< 36.0
FLUORIDE	5.58	6.10
CYANIDE	< 2.65	< 2.90
NITRATE	.317+05	.145+05
SULFATE	26.0	19.0
AMMONIUM	23.1	97.0

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - MECHANICAL HOPPER ASH

TRACE ELEMENTS	TEST CONDTITION	
	CATIONS	LOW NOX
ANTIMONY ARSENIC BARIUM BERYLLIUM BISMUTH	< .600	< .600
	< 2.00	< 2.00
	< 9.00	< 9.00
	< .540	< .970
	< 40.0	< 40.0
BORON CADMIUM CHROMIUM COBALT COPPER	< 4.00	< 4.00
	< 1.00	< 1.00
	< 3.10	< 5.90
	< 5.00	< 5.00
	< 8.00	< 15.0
IRON LEAD MANGANESE MERCURY MOLYBDENUM	< .330+04	< .670+04
	< 20.0	< 20.0
	< 70.0	< 150.
	< .000	< .000
	< 1.00	< 1.00
NICKEL SELENIUM TELLURIUM THALLIUM TIN	< 6.00	< 11.0
	< 1.00	< 1.50
	< .800	< .800
	< 50.0	< 50.0
	< 2.00	< 2.00
TITANIUM URANIUM VANADIUM ZINC ZIRCONIUM	< 360.	< 810.
	< .000	< .000
	< 20.0	< 20.0
	< 4.00	< 10.0
	< .000	< .000
ANIONS CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE	< 37.4	< 30.0
	< 19.0	< 48.3
	< 3.02	< 2.76
	< .000	< .921+05
	< 6.00	< 37.0
AMMONIUM	23.5	16.4

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPH) - BOILER OUTLET
10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASLINE		
ANTIMONY	< .600	<	.600
ARSENIC	2.00	<	4.00
BARIUM	20.0	<	5.00
BERYLLIUM	2.00	<	.270
BISMUTH	< 40.0	<	50.0
BORON	< 5.00	<	4.00
CADMIUM	< 1.00	<	1.00
CHROMIUM	23.0	<	4.80
COBALT	< 5.00	<	7.00
COPPER	60.0	<	8.00
IRON	.220+05		.310+04
LEAD	< 20.0	<	20.0
MANGANESE	360.		64.0
MERCURY	.000	*	.000
MOLYBDENUM	< 1.00	<	2.00
NICKEL	13.0	<	7.00
SELENIUM	1.40	<	1.00
TELLURIUM	.700	<	1.00
THALLIUM	40.0	<	60.0
TIN	6.60	<	2.00
TITANIUM	.240+04		320.
URANIUM	.000	*	.000
VANADIUM	< 20.0	<	30.0
ZINC	39.0	<	3.00
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	< 37.4	<	41.7
FLUORIDE	56.2	<	37.0
CYANIDE	9.96	<	5.37
NITRATE	.170	<	.190+04
SULFATE	.000	*	.000
AMMONIUM	9.06		11.6

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - BOILER OUTLET
3 MICRON CYCLONE

TRACE ELEMENTS CATIONS	TEST CONDITION		LOW NOX
	BASELINE		
ANTIMONY	< 1.00	<	.700
ARSENIC	17.0		13.0
BARIUM	310.		180.
BERYLLIUM	4.00		2.20
BISMUTH	< 70.0	<	40.0
BORON	<	<	8.00
CADMIUM	< 5.00	<	1.00
CHROMIUM	2.00		85.0
COBALT	35.0		8.00
COPPER	17.0		63.0
	150.		
IRON	.360+05		.210+05
LEAD	< 30.0	<	20.0
MANGANESE	610.		330.
MERCURY	*	*	.000
MOLYBDENUM	19.0		19.0
NICKEL	29.0		58.0
SELENIUM	2.30		5.90
TELLURIUM	1.00	<	.900
THALLIUM	< 90.0	<	50.0
TIN	26.0		4.00
TITANIUM	.480+04		.290+04
URANIUM	.000	*	.000
VANADIUM	< 40.0	<	20.0
ZINC	140.		60.0
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	< 141.	<	49.2
FLUORIDE	176.		45.2
CYANIDE	< 11.4	<	5.96
NITRATE	.630		.640+04
SULFATE	* .000	*	.000
AMMONIUM	29.7		12.3

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - BOILER OUTLET

1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS		BASELINE	
ANTIMONY	<	6.30	<
ARSENIC	*	.000	3.40
BARIUM		410.	.300
BERYLLIUM		5.30	520.
BISMUTH		2.70	5.00
			1.40
BORON	*	.000	.200+04
CADMIUM		12.0	2.90
CHROMIUM		64.0	360.
COBALT		37.0	23.0
COPPER		300.	190.
IRON		.470+05	.260+05
LEAD		170.	90.0
MANGANESE		.100+04	530.
MERCURY	*	.000	.170
MOLYBDENUM		10.0	5.00
NICKEL		560.	280.
SELENIUM	*	.000	11.0
TELLURIUM		6.70	3.00
THALLIUM		1.60	.900
TIN		.200-01	.100-01
TITANIUM		.130+05	.740+04
URANIUM	*	.000	.000
VANADIUM		290.	170.
ZINC		290.	130.
ZIRCONIUM	*	.000	.000
ANIONS			
CHLORIDE	*	.000	.000
FLUORIDE	*	.000	.000
CYANIDE	*	.000	.000
NITRATE	*	.000	.000
SULFATE	*	.000	.000
AMMONIUM	*	.000	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - BOILER OUTLET

FILTER

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< 3.10	<	3.10
ARSENIC	17.1		3.60
BARIUM	.280+04		305.
BERYLLIUM	.560	<	.100+00
BISMUTH	16.9		1.50
BORON	.123+04		863.
CADMIUM	138.		9.50
CHROMIUM	171.		323.
COBALT	.560	<	14.5
COPPER	.118+04		105.
IRON	.310+05		.123+05
LEAD	.120+04		11.1
MANGANESE	638.		279.
MERCURY	1.10		.770
MOLYBDENUM	.560	<	.340
NICKEL	192.		231.
SELENIUM	159.		10.5
TELLURIUM	33.2		.240
THALLIUM	.560	<	.450
TIN	.100-01	<	.200-01
TITANIUM	.690+04		.270+04
URANIUM	.000	*	.000
VANADIUM	186.		55.7
ZINC	5.60	<	218.
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	.000	*	.000
FLUORIDE	.000	*	.000
CYANIDE	.000	*	.000
NITRATE	.000	*	.000
SULFATE	.000	*	.000
AMMONIUM	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - BOILER OUTLET
XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASLINE	LOW NOX
ANTIMONY	< .400	< .300
ARSENIC	< .600	< .400
BARIUM	< .100+00	< .800-01
BERYLLIUM	< .200-01	< .100-01
BISMUTH	< .800	< .500
BORON	23.0	42.0
CADMIUM	< 2.00	< 1.00
CHROMIUM	< .100+00	.120
COBALT	< 8.00	< 5.00
COPPER	< 7.00	< 5.00
IRON	< 7.00	< 4.00
LEAD	< 30.0	< 20.0
MANGANESE	< 4.00	7.00
MERCURY	* .000	* .000
MOLYBDENUM	< 1.00	< .700
NICKEL	< 7.00	< 5.00
SELENIUM	< .500	< .300
TELLURIUM	< .900	< .600
THALLIUM	< 60.0	< 40.0
TIN	< .500	< .300
TITANIUM	< .900	< .600
URANIUM	* .000	* .000
VANADIUM	< 1.00	< .600
ZINC	< 3.00	< 2.00
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - BOILER OUTLET
FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS		BASELINE	
ANTIMONY	<	.340-02	< .360-02
ARSENIC		.270-01	.290-01
BARIUM	<	.800-03	.800-03
BERYLLIUM	<	.200-03	.100-03
BISMUTH	<	.510-02	.600-02
BORON		13.0	.200
CADMIUM	<	.840-02	.110-01
CHROMIUM		.540-01	.180
COBALT	<	.510-01	.480-01
COPPER		.210	.600-01
IRON		.980	1.00
LEAD	<	.170	.240
MANGANESE		.590-01	.120
MERCURY	<	.800-03	.900-03
MOLYBDENUM		.110	.460-01
NICKEL		.410	.310
SELENIUM		.670	.480
TELLURIUM	<	.680-02	.720-02
THALLIUM	<	.420	.480
TIN		.840-01	.480-01
TITANIUM	<	.680-02	.720-02
URANIUM	*	.000	.000
VANADIUM	<	.340-02	.360-02
ZINC		.200	.430
ZIRCONIUM	*	.000	.000
ANIONS			
CHLORIDE	*	.000	.000
FLUORIDE	*	.000	.000
CYANIDE	*	.000	.000
NITRATE	*	.000	.000
SULFATE	*	.000	.000
AMMONIUM	*	.000	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - BOILER OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< .30v-02	<	.300-02
ARSENIC	< .200-02	<	.200-02
BARIUM	* .000	*	.000
BERYLLIUM	* .000	*	.000
BISMUTH	* .000	*	.000
BORON	* .000	*	.000
CADMIUM	* .000	*	.000
CHROMIUM	* .000	*	.000
COBALT	* .000	*	.000
COPPER	* .000	*	.000
IRON	* .000	*	.000
LEAD	* .00v	*	.000
MANGANESE	* .00v	*	.000
MERCURY	< .400-02	<	.400-02
MOLYBDENUM	* .000	*	.000
NICKEL	* .000	*	.000
SELENIUM	* .000	*	.000
TELLURIUM	* .000	*	.000
THALLIUM	* .000	*	.000
TIN	* .000	*	.000
TITANIUM	* .000	*	.000
URANIUM	* .000	*	.000
VANADIUM	* .000	*	.000
ZINC	* .000	*	.000
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	* .000	*	.000
FLUORIDE	* .000	*	.000
CYANIDE	* .000	*	.000
NITRATE	* .00v	*	.000
SULFATE	* .000	*	.000
AMMONIUM	* .000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - ESP HOPPER ASH

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	4.30	5.20
ARSENIC	36.0	38.0
BARIUM	120.	140.
BERYLLIUM	5.00	4.80
BISMUTH	< 40.0	< 40.0
BORON	<	<
CADMIUM	4.00	4.00
CHROMIUM	1.00	3.00
COBALT	27.0	34.0
COPPER	27.0	21.0
	120.	140.
IRON	.260+05	.240+05
LEAD	110.	120.
MANGANESE	550.	500.
MERCURY	.000	.000
MOLYBDENUM	7.00	8.00
NICKEL	53.0	50.0
SELENIUM	5.50	6.80
TELLURIUM	.800	.800
THALLIUM	50.0	50.0
TIN	8.00	8.00
TITANIUM	.400+04	.360+04
URANIUM	.000	.000
VANADIUM	30.0	35.0
ZINC	350.	390.
ZIRCONIUM	.000	.000
ANIONS		
CHLORIDE	< 38.9	< 34.2
FLUORIDE	6.89	15.2
CYANIDE	3.13	2.76
NITRATE	.990+04	.313+05
SULFATE	224.	83.0
AMMONIUM	27.9	48.9

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - ESP OUTLET
10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASLINE	
ANTIMONY	< 3.10	< .600
ARSENIC	* .000	< 4.00
BARIUM	.330+04	< 5.00
BERYLLIUM	< .440	.470
BISMUTH	4.50	< 40.0
BORON	< 5.00	* .000
CADMIUM	113.	< 1.00
CHROMIUM	310.	5.20
COBALT	.440	< 6.00
COPPER	387.	< 6.00
IRON	.280+05	.380+04
LEAD	.104+04	20.0
MANGANESE	730.	81.0
MERCURY	* .000	< .200-01
MOLYBDENUM	70.5	< 2.00
NICKEL	274.	< 7.00
SELENIUM	* .000	< 1.00
TELLURIUM	13.4	< .900
THALLIUM	4.40	< 50.0
TIN	.300-01	< 2.00
TITANIUM	.930	430.
URANIUM	* .000	.000
VANADIUM	144.	< 20.0
ZINC	.150+04	< 3.00
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT CONCENTRATION - (PPM) -
3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS		BASELINE	
ANTIMONY	<	3.10	<
ARSENIC	*	.000	* 4.50
BARIUM		.330+04	
BERYLLIUM	<	.440	< 27.8
BISMUTH		4.50	.140
			4.60
BORON	*	.000	*
CADMIUM		113.	.000
CHROMIUM		310.	20.2
COBALT	<	.440	947.
COPPER		387.	52.0
			578.
IRON		.280+05	.320+05
LEAD		.104+04	171.
MANGANESE		730.	729.
MERCURY	*	.000	* .000
MOLYBDENUM		70.5	18.2
NICKEL		274.	.102+04
SELENIUM	*	.000	* .000
TELLURIUM		13.4	4.30
THALLIUM		4.40	1.30
TIN		.300-01	.200-01
TITANIUM		.930	.680+04
URANIUM	*	.000	* .000
VANADIUM		144.	79.4
ZINC	*	.150+04	509.
ZIRCONIUM		.000	.000
ANIONS			
CHLORIDE	*	.000	* .000
FLUORIDE	*	.000	* .000
CYANIDE	*	.000	* .000
NITRATE	*	.000	* .000
SULFATE	*	.000	* .000
AMMONIUM	*	.000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - ESP OUTLET
1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< 3.10	<	5.10
ARSENIC	* .000	*	.000
BARIUM	.330+04		.171+04
BERYLLIUM	< .440	<	.260
BISMUTH	4.50		20.0
BORON	* .000	*	.000
CADMIUM	113.		60.9
CHROMIUM	310.		.211+04
COBALT	.440		71.2
COPPER	367.		677.
IRON			
LEAD	.280+05		.340+05
MANGANESE	.10+04		645.
MERCURY	730.		.107+04
MOLYBDENUM	* .000	*	.000
	70.5		55.6
NICKEL	274.		.199+04
SELENIUM	* .000	*	.000
TELLURIUM	13.4		4.30
THALLIUM	4.40		5.60
TIN	.30+01		.200+01
TITANIUM	.930		.119+05
URANIUM	* .000	*	.000
VANADIUM	144.		250.
ZINC	.150+04		330.
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	* .000	*	.000
FLUORIDE	* .000	*	.000
CYANIDE	* .000	*	.000
NITRATE	* .000	*	.000
SULFATE	* .000	*	.000
AMMONIUM	* .000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - ESP OUTLET
FILTER

TRACE ELEMENTS	TEST CONDITION		LOW NOX	
CATIONS	BASELINE			
ANTIMONY	< 3.10	<	3.10	
ARSENIC	* .000	*	.000	
BARIUM	.330+04		.171+04	
BERYLLIUM	< .440	<	.260	
BISMUTH	4.50		20.0	
BORON	* .000	*	.000	
CADMIUM	113.		60.9	
CHROMIUM	310.		.211+04	
COBALT	.440	<	71.2	
COPPER	367.		677.	
IRON	.280+05		.340+05	
LEAD	.104+04		645.	
MANGANESE	730.		.107+04	
MERCURY	* .000	*	.000	
MOLYBDENUM	70.5		55.6	
NICKEL	274.		.199+04	
SELENIUM	* .000	*	.000	
TELLURIUM	13.4		4.30	
THALLIUM	4.40		3.60	
TIN	.300-01		.200-01	
TITANIUM	.930		.119+05	
URANIUM	* .000	*	.000	
VANADIUM	144.		250.	
ZINC	.150+04		330.	
ZIRCONIUM	* .000	*	.000	
ANIONS				
CHLORIDE	* .000	*	.000	
FLUORIDE	* .000	*	.000	
CYANIDE	* .000	*	.000	
NITRATE	* .000	*	.000	
SULFATE	* .000	*	.000	
AMMONIUM	* .000	*	.000	

SPREADER STONER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT CONCENTRATION - (PPM) -
XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	< 3.00	< .400
ARSENIC	< .100-01	< .500
BARIUM	< 48.8	< .100+00
BERYLLIUM	< .600	< .100-01
BISMUTH	< 3.60	< .700
BORON	< 1.20	32.0
CADMIUM	.220	2.00
CHROMIUM	< .120	6.10
COBALT	< .740	< 6.00
COPPER	< .400	< 6.00
IRON	8.10	< 12.0
LEAD	< .500	< 20.0
MANGANESE	.140	< 3.00
MERCURY	.500-01	* .000
MOLYBDENUM	1.14	< .500
NICKEL	3.00	< 6.00
SELENIUM	< .270	< .400
TELLURIUM	< .100-01	< .700
THALLIUM	< .100-01	< 50.0
TIN	< .100-01	31.0
TITANIUM	< .100+00	< .700
URANIUM	* .000	* .000
VANADIUM	< .100+00	< .800
ZINC	.900	< 2.00
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT CONCENTRATION - (PPH) -
FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	< .270-02	< .340-02
ARSENIC	< .380-01	< .490-01
BARIUM	< .270-02	< .860-02
BERYLLIUM	< .100-03	< .100-03
BISMUTH	< .550-02	< .510-02
BORON	11.0	1.80
CADMIUM	< .140-01	< .860-02
CHROMIUM	< .680-01	.120
COBALT	< .550-01	< .510-01
COPPER	< .480-01	.210
IRON	.310	.390
LEAD	< .200	< .170
MANGANESE	< .550-01	< .390-01
MERCURY	< .700-03	< .900-03
MOLYBDENUM	< .610-02	< .290-01
NICKEL	.660-01	.100+00
SELENIUM	.380	.610
TELLURIUM	< .680-02	< .690-02
THALLIUM	< .410	< .430
TIN	.100+00	.660-01
TITANIUM	< .680-02	< .690-02
URANIUM	* .000	* .000
VANADIUM	< .340-02	< .340-02
ZINC	.340-01	.600-01
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT CONCENTRATION - (PPM) - ESP OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
	CATIONS	BASELINE	
ANTIMONY	<	.300-02	<
ARSENIC	<	.300-02	<
BARIUM	*	.000	*
BERYLLIUM	*	.000	*
BISMUTH	*	.000	*
BORON	*	.000	*
CADMIUM	*	.000	*
CHROMIUM	*	.000	*
COBALT	*	.000	*
COPPER	*	.000	*
IRON	*	.000	*
LEAD	*	.000	*
MANGANESE	*	.000	*
MERCURY	<	.400-02	<
MOLYBDENUM	*	.000	*
NICKEL	*	.000	*
SELENIUM	*	.000	*
TELLURIUM	*	.000	*
THALLIUM	*	.000	*
TIN	*	.000	*
TITANIUM	*	.000	*
URANIUM	*	.000	*
VANADIUM	*	.000	*
ZINC	*	.000	*
ZIRCONIUM	*	.000	*
ANIONS			
CHLORIDE	*	.000	*
FLUORIDE	*	.000	*
CYANIDE	*	.000	*
NITRATE	*	.000	*
SULFATE	*	.000	*
AMMONIUM	*	.000	*

APPENDIX D-1
TRACE ELEMENT FLOW RATES
(kilograms per minute)

Symbols appearing in the tables:

DSCM	Dry Standard Cubic Meter
ESP	Electrostatic Precipitator
KG	Kilogram
MCG	Microgram
MIN	Minute
PPM	Part per million by weight
<	Less than
*	Sample not analyzed for the particular element/or ionic specie
N	Sample not analyzed
-	Concentration in the sample is less than the concentration in the blank

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) - FUEL INLET

TRACE ELEMENTS		TEST CONDITION	
CATIONS		BASELINE	LOW NOX
ANTIMONY	<	.416-04	< .412-04
ARSENIC	<	.416-04	< .412-04
BARIUM		.281-01	.134-01
BERYLLIUM		.832-04	.412-04
BISMUTH	<	.208-03	< .206-03
BORON		.374-02	.330-02
CADMIUM	<	.208-04	< .206-04
CHROMIUM		.478-03	.453-03
COBALT		.663-03	.288-03
COPPER		.137-02	.109-02
IRON		.493	.589
LEAD	<	.624-03	< .618-03
MANGANESE		.102-01	.120-01
MERCURY		.416-05	.412-05
MOLYBDENUM	<	.624-03	< .618-03
NICKEL		.166-03	.144-03
SELENIUM		.416-04	.165-03
TELLURIUM	<	.416-04	< .412-04
THALLIUM	<	.416-03	< .412-03
TIN		.624-04	.515-02
TITANIUM		.179	.886-01
URANIUM		.312-04	.227-04
VANADIUM		.195-02	.124-02
ZINC		.119-02	.109-02
ZIRCONIUM		.291-02	.783-02
ANIONS			
CHLORIDE	*	.000	* .000
FLUORIDE	*	.000	* .000
CYANIDE	*	.000	* .000
NITRATE	*	.000	* .000
SULFATE	*	.000	* .000
AMMONIUM	*	.000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) - BOTTOM ASH

TRACE ELEMENTS		TEST CONDITION	
CATIONS	BASELINE	LOW NOX	
ANTIMONY	< .455-05	<	.591-05
ARSENIC	.152-04		.253-04
BARIUM	.182-02		.127-02
BERYLLIUM	.607-05		.110-04
BISMUTH	< .303-03	<	.338-03
BORON	< .372-04	<	.422-04
CADMIUM	< .758-05	<	.844-05
CHROMIUM	.162-03		.220-03
COBALT	< .379-04	<	.507-04
COPPER	.318-03		.296-03
IRON	.227		.262
LEAD	< .152-03	<	.169-03
MANGANESE	.409-02		.473-02
MERCURY	* .000	*	.000
MOLYBDENUM	< .758-05	<	.169-04
NICKEL	.607-04	<	.591-04
SELENIUM	.303-05		.177-04
TELLURIUM	< .607-05	<	.760-05
THALLIUM	< .379-03	<	.507-03
TIN	.394-02		.329-02
TITANIUM	.318-01		.338-01
URANIUM	* .000	*	.000
VANADIUM	< .152-03	<	.169-03
ZINC	.129-03		.160-03
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	< .250-03	<	.304-03
FLUORIDE	.423-04		.515-04
CYANIDE	< .201-04	<	.245-04
NITRATE	.242		.122
SULFATE	.197-03		.160-03
AMMONIUM	.175-03		.819-03

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) - MECHANICAL HOPPER ASH

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASLINE		
ANTIMONY	< .425-05	<	.238-05
ARSENIC	.142-04		.792-05
BARIUM	.637-04		.356-04
BERYLLIUM	.382-05		.384-05
BISMUTH	< .283-03	<	.158-03
BORON	< .283-04	<	.158-04
CADMIUM	< .708-05	<	.396-05
CHROMIUM	.220-04		.234-04
COBALT	< .354-04	<	.198-04
COPPER	.567-04		.594-04
IRON	.234-01		.265-01
LEAD	< .142-03	<	.792-04
MANGANESE	.496-03		.594-03
MERCURY	* .000	*	.000
MOLYBDENUM	< .708-05	<	.396-05
NICKEL	< .425-04	<	.435-04
SELENIUM	.708-05		.594-05
TELLURIUM	< .567-05	<	.317-05
THALLIUM	< .354-03	<	.198-03
TIN	.142-04	<	.792-05
TITANIUM	.248-02		.321-02
URANIUM	* .000	*	.000
VANADIUM	< .142-03	<	.792-04
ZINC	.283-04		.396-04
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	< .265-03	<	.119-03
FLUORIDE	.134-03		.191-03
CYANIDE	< .214-04	<	.109-04
NITRATE	* .000	*	.365
SULFATE	< .425-04	<	.146-03
AMMONIUM	.16/-03		.727-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

10 MICRON CYCLONE

TRACE ELEMENTS		TEST CONDITION	
CATIONS	BASELINE	LOW NOX	
ANTIMONY	< .231-04	< .205-04	
ARSENIC	.770-04	.103-03	
BARIUM	.770-03	< .128-03	
BERYLLIUM	.770-04	.693-05	
BISMUTH	< .154-02	< .128-02	
BORON	< .193-03	< .103-03	
CADMIUM	< .365-04	.257-04	
CHROMIUM	.886-03	.123-03	
COBALT	< .193-03	< .180-03	
COPPER	.231-02	< .205-03	
IRON	.847	.796-01	
LEAD	< .770-03	.513-03	
MANGANESE	.139-01	.164-02	
MERCURY	* .000	* .000	
MOLYBDENUM	< .385-04	< .513-04	
NICKEL	.501-03	< .180-03	
SELENIUM	.539-04	.257-04	
TELLURIUM	< .270-04	< .257-04	
THALLIUM	< .154-02	< .154-02	
TIN	.254-03	< .513-04	
TITANIUM	.924-01	.821-02	
URANIUM	* .000	* .000	
VANADIUM	< .770-03	< .770-03	
ZINC	.150-02	< .770-04	
ZIRCONIUM	* .000	* .000	
ANIONS			
CHLORIDE	< .144-02	< .107-02	
FLUORIDE	.216-02	.950-03	
CYANIDE	.364-03	.865-04	
NITRATE	.655-05	.488-01	
SULFATE	* .000	* .000	
AMMONIUM	.349-03	.302-03	

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
	CATIONS	ANIONS
	BASELINE	LOW NOX
ANTIMONY	< .103-04	< .124-05
ARSENIC	.176-03	.231-04
BARIUM	.321-02	.319-03
BERYLLIUM	.414-04	.390-05
BISMUTH	< .724-03	< .710-04
BORON	< .517-04	< .142-04
CADMIUM	< .207-04	< .177-05
CHROMIUM	.362-03	.151-03
COBALT	.176-03	.142-04
COPPER	.155-02	.112-03
IRON	.372	.373-01
LEAD	< .310-03	< .355-04
MANGANESE	.631-02	.586-03
MERCURY	.000	.000
MOLYBDENUM	.196-03	.337-04
NICKEL	.300-03	.103-03
SELENIUM	.238-04	.105-04
TELLURIUM	< .103-04	< .160-05
THALLIUM	.931-03	.687-04
TIN	.269-03	.710-05
TITANIUM	.496-01	.515-02
URANIUM	.000	.000
VANADIUM	< .414-03	< .355-04
ZINC	.145-02	.106-03
ZIRCONIUM	.000	.000
CHLORIDE	< .146-02	< .872-04
FLUORIDE	< .182-02	< .602-04
CYANIDE	< .118-03	< .703-05
NITRATE	.651-05	.114-01
SULFATE	.000	.000
AMMONIUM	.307-03	.218-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET
1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< .867-05	<	.134-05
ARSENIC	.000	*	.118-06
BARIUM	.577-03		.126-03
BERYLLIUM	.748-05		.197-05
BISMUTH	.380-05	<	.553-06
BORON	.000		.790-03
CAESIUM	.169-04	*	.115-05
CHROMIUM	.901-04		.142-03
COBALT	.521-04		.908-05
COPPER	.422-03		.750-04
IRON	.662-01		.103-01
LEAD	.239-03		.355-04
MANGANESE	.141-02		.209-03
MERCURY	.000	*	.671-07
MOLYBDENUM	.141-04		.197-05
NICKEL	.789-03		.111-03
SELENIUM	.000	*	.434-05
TELLURIUM	.943-05		.118-05
THALLIUM	.253-05		.355-06
TIN	.262-07	<	.395-08
TITANIUM	.183-01		.292-02
URANIUM	.000	*	.000
VANADIUM	.408-03		.671-04
ZINC	.408-03		.513-04
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	.000	*	.000
FLUORIDE	.000	*	.000
CYANIDE	.000	*	.000
NITRATE	.000	*	.000
SULFATE	.000	*	.000
AMMONIUM	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) -
BOILER OUTLET

FILTER

TRACE ELEMENTS	TEST CONDITION	
	BASELINE	LOW NOX
CATIONS		
ANTIMONY	< .139-05	< .141-05
ARSENIC	.766-05	.172-05
BARIUM	.125-02	.139-03
BERYLLIUM	< .251-06	.454-07
BISMUTH	.757-05	.681-06
BORON	.551-03	.392-03
CADMIUM	.618-04	.431-05
CHROMIUM	.765-04	.147-03
COBALT	.251-06	.658-05
COPPER	.521-03	.479-04
IRON	.139-01	.558-02
LEAD	.538-03	.504-05
MANGANESE	.375-03	.127-03
MERCURY	.493-06	.349-06
MOLYBDENUM	< .251-06	.154-06
NICKEL	.860-04	.105-03
SELENIUM	.712-04	.477-05
TELLURIUM	.149-04	.109-06
THALLIUM	< .251-06	.204-06
TIN	< .448-08	.908-08
TITANIUM	.309-02	.123-02
URANIUM	* .000	* .000
VANADIUM	.835-04	.253-04
ZINC	< .251-05	.989-04
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET
XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASELINE	
ANTIMONY	< .675-05	< .816-05
ARSENIC	< .101-04	< .109-04
BARIUM	< .169-05	< .218-05
BERYLLIUM	< .337-06	< .272-06
BISMUTH	< .135-04	< .136-04
BORON	.386-03	.114-02
CADMIUM	< .337-04	< .272-04
CHROMIUM	< .169-05	.326-05
COBALT	< .135-03	< .136-03
COPPER	< .118-03	< .136-03
IRON	< .118-03	< .109-03
LEAD	< .506-03	< .544-03
MANGANESE	< .675-04	< .190-03
MERCURY	* .000	* .000
MOLYBDENUM	< .169-04	< .190-04
NICKEL	< .118-03	< .136-03
SELENIUM	< .843-05	< .816-05
TELLURIUM	< .152-04	< .163-04
THALLIUM	< .101-02	< .109-02
TIN	< .843-05	< .816-05
TITANIUM	< .152-04	< .163-04
URANIUM	* .000	* .000
VANADIUM	< .169-04	< .163-04
ZINC	< .506-04	< .544-04
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET
FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	<	.618-06	<
ARSENIC		.491-05	.744-06
BARIUM	<	.145-06	.599-05
BERYLLIUM	<	.363-07	.165-06
BISMUTH	<	.927-06	.207-07
			.124-05
BORON		.236-02	<
CADMIUM	<	.153-05	.413-04
CHROMIUM		.981-05	.227-05
COBALT	<	.927-05	.372-04
COPPER		.362-04	.991-05
			.124-04
IRON		.178-03	.207-03
LEAD	<	.309-04	.496-04
MANGANESE		.107-04	.248-04
MERCURY	<	.145-06	.186-06
MOLYBDENUM		.200-04	.950-05
NICKEL		.745-04	.640-04
SELENIUM		.122-03	.991-04
TELLURIUM	<	.124-05	.149-05
THALLIUM	<	.763-04	.991-04
TIN		.153-04	.991-05
TITANIUM	<	.124-05	<
URANIUM	*	.000	.149-05
VANADIUM	<	.618-06	.000
ZINC		.363-04	.744-06
ZIRCONIUM	*	.000	.888-04
			.000
ANIONS			
CHLORIDE	*	.000	.000
FLUORIDE	*	.000	.000
CYANIDE	*	.000	.000
NITRATE	*	.000	.000
SULFATE	*	.000	.000
AMMONIUM	*	.000	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

2ND & 3RD IMPINGERS

TRACE ELEMENTS CATIONS	TEST CONDITION		LOW NOX
	BASELINE		
ANTIMONY	< .589-06	< .101-05	
ARSENIC	< .393-06	< .670-06	
BARIUM	* .000	* .000	
BERYLLIUM	* .000	* .000	
BISMUTH	* .000	* .000	
BORON	* .000	* .000	
CADMIUM	* .000	* .000	
CHROMIUM	* .000	* .000	
COBALT	* .000	* .000	
COPPER	* .000	* .000	
IRON	* .000	* .000	
LEAD	* .000	* .000	
MANGANESE	* .000	* .000	
MERCURY	< .785-06	< .134-05	
MOLYBDENUM	* .000	* .000	
NICKEL	* .000	* .000	
SELENIUM	* .000	* .000	
TELLURIUM	* .000	* .000	
THALLIUM	* .000	* .000	
TIN	* .000	* .000	
TITANIUM	* .000	* .000	
URANIUM	* .000	* .000	
VANADIUM	* .000	* .000	
ZINC	* .000	* .000	
ZIRCONIUM	* .000	* .000	
ANIONS			
CHLORIDE	* .000	* .000	
FLUORIDE	* .000	* .000	
CYANIDE	* .000	* .000	
NITRATE	* .000	* .000	
SULFATE	* .000	* .000	
AMMONIUM	* .000	* .000	

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- BOILER OUTLET

TRACE ELEMENTS		TEST CONDITION	
CATIONS		BASELINE	LOW NOX
ANTIMONY	<	.517-04	<
ARSENIC		.276-03	.344-04
BARIUM		.581-02	.145-03
BERYLLIUM		.126-03	.715-03
BISMUTH	<	.229-02	.131-04
			.137-02
BORON	<	.355-02	<
CADMIUM	<	.173-03	.248-02
CHROMIUM	<	.143-02	.624-04
COBALT	<	.565-03	.603-03
COPPER	<	.496-02	.355-03
			.580-03
IRON		1.30	.133
LEAD	<	.233-02	.118-02
MANGANESE		.220-01	.278-02
MERCURY		.142-05	.194-05
MOLYBDENUM	<	.286-03	.116-03
NICKEL		.187-02	<
SELENIUM		.279-03	.694-03
TELLURIUM	<	.780-04	.153-03
THALLIUM	<	.356-02	.464-04
TIN		.547-03	.282-02
			.765-04
TITANIUM		.163	.175-01
URANIUM	*	.000	.000
VANADIUM	<	.169-02	.915-03
ZINC		.345-02	.477-03
ZIRCONIUM	*	.000	.000
ANIONS			
CHLORIDE	<	.290-02	<
FLUORIDE		.398-02	.116-02
CYANIDE		.504-03	.103-02
NITRATE		.131-04	.935-04
SULFATE	*	.000	.601-01
			.000
AMMONIUM		.656-03	.324-03

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) - ESP HOPPER ASH

TRACE ELEMENTS	TEST CONDITION	
	BASELINE	LOW NOX
CATIONS		
ANTIMONY	.128-04	.819-05
ARSENIC	.107-03	.599-04
BARIUM	.357-03	.221-03
BERYLLIUM	.149-04	.756-05
BISMUTH	.119-03	.630-04
BORON	.117-04	.630-05
CADMIUM	.297-05	.473-05
CHROMIUM	.803-04	.536-04
COBALT	.803-04	.331-04
COPPER	.357-03	.221-03
IRON	.773-01	.378-01
LEAD	.327-03	.169-03
MANGANESE	.164-02	.788-03
MERCURY	.000	.000
MOLYBDENUM	.208-04	.126-04
NICKEL	.158-03	.788-04
SELENIUM	.164-04	.107-04
TELLURIUM	.238-05	.126-05
THALLIUM	.149-03	.788-04
TIN	.238-04	.126-04
TITANIUM	.119-01	.567-02
URANIUM	.000	.000
VANADIUM	.892-04	.551-04
ZINC	.104-02	.614-03
ZIRCONIUM	.000	.000
ANIONS		
CHLORIDE	.116-03	.539-04
FLUORIDE	.203-04	.239-04
CYANIDE	.931-05	.435-05
NITRATE	.294-01	.493-01
SULFATE	.666-03	.131-03
AMMONIUM	.629-04	.770-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASELINE	
ANTIMONY	< .381-07	< .177-07
ARSENIC	* .000	< .118-06
BARIUM	< .406-04	< .147-06
BERYLLIUM	< .541-08	< .139-07
BISMUTH	< .553-07	< .118-05
BORON	< .615-07	* .000
CADMIUM	< .139-05	< .295-07
CHROMIUM	< .381-05	< .153-06
COBALT	< .541-08	< .177-06
COPPER	< .476-05	< .236-06
IRON	< .344-03	< .112-03
LEAD	< .128-04	< .590-06
MANGANESE	< .897-05	< .239-05
MERCURY	* .000	< .590-09
MOLYBDENUM	< .867-06	< .590-07
NICKEL	< .337-05	< .206-06
SELENIUM	* .000	< .295-07
TELLURIUM	< .165-06	< .265-07
THALLIUM	< .541-07	< .177-05
TIN	< .369-09	< .590-07
TITANIUM	< .114-07	< .127-04
URANIUM	* .000	* .000
VANADIUM	< .177-05	< .590-06
ZINC	< .184-04	< .884-07
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) - ESP OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS		BASELINE	
ANTIMONY	<	.421-07	< .946-07
ARSENIC	*	.000	* .000
BARIUM	<	.449-04	< .584-06
BERYLLIUM	<	.596-08	< .294-08
BISMUTH		.612-07	.967-07
BORON	*	.000	* .000
CADMIUM		.153-05	.425-06
CHROMIUM		.421-05	.199-04
COBALT	<	.598-08	.673-06
COPPER		.527-05	.121-04
IRON		.381-03	.673-03
LEAD		.142-04	.360-05
MANGANESE		.592-05	.153-04
MERCURY	*	.000	* .000
MOLYBDENUM		.558-06	.383-06
NICKEL		.375-05	.214-04
SELENIUM	*	.000	* .000
TELLURIUM		.182-06	.904-07
THALLIUM		.598-07	.273-07
TIN		.408-09	.420-09
TITANIUM		.126-07	.143-03
URANIUM	*	.000	* .000
VANADIUM		.195-05	.167-05
ZINC		.204-04	.650-05
ZIRCONIUM	*	.000	* .000
ANIONS			
CHLORIDE	*	.000	* .000
FLUORIDE	*	.000	* .000
CYANIDE	*	.000	* .000
NITRATE	*	.000	* .000
SULFATE	*	.000	* .000
AMMONIUM	*	.000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)-
ESP OUTLET
1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASLINE	
ANTIMONY	< .898-07	< .143-06
ARSENIC	* .000	* .000
BARIUM	.958-04	.788-04
BERYLLIUM	< .127-07	< .120-07
BISMUTH	.130-06	.923-06
BORON	* .000	* .000
CADMIUM	.327-05	.281-05
CHROMIUM	.897-05	.973-04
COBALT	< .127-07	.329-05
COPPER	.112-04	.312-04
IRON	.811-03	.157-02
LEAD	.302-04	.298-04
MANGANESE	.211-04	.495-04
MERCURY	* .000	* .000
MOLYBDENUM	.204-05	.257-05
NICKEL	.794-05	.919-04
SELENIUM	* .000	* .000
TELLURIUM	.388-06	.198-06
THALLIUM	.127-06	.166-06
TIN	.869-09	.923-09
TITANIUM	.269-07	.549-03
URANIUM	* .000	* .000
VANADIUM	.416-05	.115-04
ZINC	.434-04	.152-04
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

FILTER

TRACE ELEMENTS	TEST CONDITION		
	CATIONS	BASELINE	LOW NOX
ANTIMONY ARSENIC BARIUM BERYLLIUM BISMUTH	<	.447-07	<
	*	.000	*
	<	.476-04	<
		.634-08	
		.649-07	
BORON CADMIUM CHROMIUM COBALT COPPER	*	.000	*
		.163-05	
	<	.447-05	
		.634-08	
		.559-05	
IRON LEAD MANGANESE MERCURY MOLYBDENUM		.404-03	
		.150-04	
	*	.105-04	*
		.000	
		.102-05	
NICKEL SELENIUM TELLURIUM THALLIUM TIN	*	.395-05	*
		.000	
		.193-06	
		.634-07	
		.433-09	
TITANIUM URANIUM VANADIUM ZINC ZIRCONIUM	*	.134-07	*
		.000	
		.207-05	
	*	.216-04	*
		.000	
ANIONS CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
AMMONIUM	*	.000	*

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET
XAO-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASELINE	
ANTIMONY	< .358-04	< .470-05
ARSENIC	< .119-06	< .588-05
BARIUM	< .583-03	< .118-05
BERYLLIUM	< .717-05	< .118-06
BISMUTH	< .454-04	< .823-05
BORON	< .143-04	< .376-03
CADMIUM	< .263-05	< .235-04
CHROMIUM	< .143-05	< .717-04
COBALT	< .884-05	< .705-04
COPPER	< .478-05	< .705-04
IRON	< .967-04	< .141-03
LEAD	< .597-05	< .235-03
MANGANESE	< .167-05	< .353-04
MERCURY	< .597-06	< .000
MOLYBDENUM	< .136-04	< .588-05
NICKEL	< .358-04	< .705-04
SELENIUM	< .322-05	< .470-05
TELLURIUM	< .119-06	< .823-05
THALLIUM	< .119-06	< .588-03
TIN	< .119-06	< .364-03
TITANIUM	< .119-05	< .823-05
URANIUM	< .000	< .000
VANADIUM	< .119-05	< .941-05
ZINC	< .107-04	< .235-04
ZIRCONIUM	< .000	< .000
ANIONS		
CHLORIDE	< .000	< .000
FLUORIDE	< .000	< .000
CYANIDE	< .000	< .000
NITRATE	< .000	< .000
SULFATE	< .000	< .000
AMMONIUM	< .000	< .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN)- ESP OUTLET

FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASELINE	
ANTIMONY	< .430-06	< .423-06
ARSENIC	< .604-05	< .610-05
BARIUM	< .430-06	< .107-05
BERYLLIUM	< .159-07	< .125-07
BISMUTH	< .875-06	< .635-06
BORON	< .175-02	< .224-03
CADMIUM	< .223-05	< .107-05
CHROMIUM	< .108-04	< .149-04
COBALT	< .875-05	< .635-05
COPPER	< .764-05	< .262-04
IRON	< .493-04	< .486-04
LEAD	< .318-04	< .212-04
MANGANESE	< .875-05	< .486-05
MERCURY	< .111-06	< .112-06
MOLYBDENUM	< .970-06	< .361-05
NICKEL	< .108-04	< .125-04
SELENIUM	< .604-04	< .760-04
TELLURIUM	< .108-05	< .859-06
THALLIUM	< .652-04	< .535-04
TIN	< .159-04	< .107-04
TITANIUM	< .108-05	< .859-06
URANIUM	< .000	< .000
VANADIUM	< .541-06	< .423-06
ZINC	< .541-05	< .747-05
ZIRCONIUM	< .000	< .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) - ESP OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< .528-06	<	.503-06
ARSENIC	< .528-06	<	.336-06
BARIUM	* .000	*	.000
BERYLLIUM	* .000	*	.000
BISMUTH	* .000	*	.000
BORON	* .000	*	.000
CADMIUM	* .000	*	.000
CHROMIUM	* .000	*	.000
COBALT	* .000	*	.000
COPPER	* .000	*	.000
IRON	* .000	*	.000
LEAD	* .000	*	.000
MANGANESE	* .000	*	.000
MERCURY	< .704-06	<	.671-06
MOLYBDENUM	* .000	*	.000
NICKEL	* .000	*	.000
SELENIUM	* .000	*	.000
TELLURIUM	* .000	*	.000
THALLIUM	* .000	*	.000
TIN	* .000	*	.000
TITANIUM	* .000	*	.000
URANIUM	* .000	*	.000
VANADIUM	* .000	*	.000
ZINC	* .000	*	.000
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	* .000	*	.000
FLUORIDE	* .000	*	.000
CYANIDE	* .000	*	.000
NITRATE	* .000	*	.000
SULFATE	* .000	*	.000
AMMONIUM	* .000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (KG/MIN) - ESP OUTLET

TRACE ELEMENTS	TEST CONDITION		LOW NOX
	CATIONS	BASELINE	
ANTIMONY	<	.370-04	< .596-05
ARSENIC	<	.669-05	< .124-04
BARIUM	<	.812-03	< .122-03
BERYLLIUM	<	.721-05	< .165-06
BISMUTH		.466-04	< .115-04
BORON	<	.176-02	< .600-03
CADMIUM		.127-04	< .293-04
CHROMIUM		.337-04	< .254-03
COBALT	<	.176-04	< .827-04
COPPER		.392-04	< .156-03
IRON		.209-02	< .335-02
LEAD		.110-03	< .306-03
MANGANESE		.610-04	< .133-03
MERCURY		.141-05	< .784-06
MOLYBDENUM		.195-04	< .138-04
NICKEL		.656-04	< .244-03
SELENIUM	<	.637-04	< .807-04
TELLURIUM		.215-05	< .951-05
THALLIUM		.658-04	< .643-03
TIN		.165-04	< .375-03
TITANIUM		.234-05	< .998-03
URANIUM	*	.000	* .000
VANADIUM		.117-04	< .296-04
ZINC		.120-03	< .607-04
ZIRCONIUM	*	.000	* .000
ANIONS			
CHLORIDE	*	.000	* .000
FLUORIDE	*	.000	* .000
CYANIDE	*	.000	* .000
NITRATE	*	.000	* .000
SULFATE	*	.000	* .000
AMMONIUM	*	.000	* .000

APPENDIX D-2
TRACE ELEMENT FLOWRATES
(micrograms/joules)

SPREADER STOKER INDUSTRIAL BOILER FUEL INLET
TRACE ELEMENT ANALYSIS - (MCG/JOULE) -

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASELINE	
ANTHRONY	< .809-05	< .834-05
ARSENIC	< .809-05	< .834-05
BARIUM	.546-02	.271-02
BERYLLIUM	.162-04	.834-05
BISMUTH	< .405-04	< .417-04
BORON	.729-03	.667-03
CADMIUM	< .405-05	< .417-05
CHROMIUM	.931-04	.918-04
COBALT	.130-03	.542-04
COPPER	.271-03	.221-03
IRON	.959-01	.119
LEAD	< .121-03	< .125-03
MANGANESE	.198-02	.242-02
MERCURY	.809-06	.834-06
MOLYBDENUM	< .121-03	< .125-03
NICKEL	.324-04	.292-04
SELENIUM	.609-05	.334-04
TELLURIUM	< .809-05	< .834-05
THALLIUM	< .609-04	< .834-04
TIN	.121-04	.104-02
TITANIUM	.348-01	.179-01
URANIUM	.607-05	.459-05
VANADIUM	.380-03	.250-03
ZINC	.231-03	.221-03
ZIRCONIUM	.567-03	.159-02
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOTTOM ASH

TRACE ELEMENTS		TEST CONDITION	
CATIONS	BASELINE		LOW NOX
ANTIMONY	< .885-06	<	.120-05
ARSENIC	.295-05		.513-05
BARIUM	.354-03		.256-03
BERYLLIUM	.118-05		.222-05
BISMUTH	.590-04	<	.684-04
BORON	<	<	.854-05
CADMIUM	.738-05	<	.171-05
CHROMIUM	.148-05	<	.444-04
COBALT	.354-04	<	.103-04
COPPER	.738-05	<	.598-04
	.620-04		
IRON	.443-01		.530-01
LEAD	.295-04	<	.342-04
MANGANESE	.797-03	<	.957-03
MERCURY	.000	*	.000
MOLYBDENUM	.148-05	<	.342-05
NICKEL	<	<	.120-04
SELENIUM	.118-04	<	.359-05
TELLURIUM	.590-06	<	.154-05
THALLIUM	.118-05	<	.103-03
TIN	.738-04	<	.666-03
	.767-03		
TITANIUM	.620-02		.684-02
URANIUM	.000	*	.000
VANADIUM	.295-04	<	.342-04
ZINC	.251-04	<	.325-04
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	< .488-04	<	.615-04
FLUORIDE	.823-05		.104-04
CYANIDE	.391-03	<	.496-05
NITRATE	.471-01		.248-01
SULFATE	.384-04		.325-04
AMMONIUM	.341-04		.166-03

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE) - MECHANICAL HOPPER ASH

TRACE ELEMENTS		TEST CONDITION	
CATIONS	BASELINE		LOW NOX
ANTIMONY	< .827-06	<	.481-06
ARSENIC	.276-05		.160-05
BARIUM	.124-04		.721-05
BERYLLIUM	.744-06		.777-06
BISMUTH	< .551-04	<	.320-04
BORON	< .551-05	<	.320-05
CADMIUM	< .138-05	<	.801-06
CHROMIUM	.427-05		.473-05
COBALT	< .689-05	<	.401-05
COPPER	.110-04		.120-04
IRON	.455-02		.537-02
LEAD	< .276-04	<	.160-04
MANGANESE	.965-04		.120-03
MERCURY	.000	*	.000
MOLYBDENUM	< .138-05	<	.801-06
NICKEL	< .627-05	<	.881-05
SELENIUM	.138-05		.120-05
TELLURIUM	< .110-05	<	.641-06
THALLIUM	< .689-04	<	.401-04
TIN	.276-05	<	.160-05
TITANIUM	.48-03		.649-03
URANIUM	.000	*	.000
VANADIUM	< .276-04	<	.160-04
ZINC	.551-05		.801-05
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	< .515-04	<	.240-04
FLUORIDE	.262-04		.387-04
CYANIDE	< .416-05	<	.221-05
NITRATE	* .000		.738-01
SULFATE	< .827-05	<	.296-04
AMMONIUM	.324-04		.147-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OULET

10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< .450-05	<	.416-05
ARSENIC	.150-04		.208-04
BARIUM	.150-03	<	.260-04
BERYLLIUM	.150-04		.140-05
BISMUTH	.300-03	<	.260-03
BORON	.375-04	<	.208-04
CADMIUM	.750-05	<	.520-05
CHROMIUM	.175-03		.250-04
COBALT	.375-04	<	.364-04
COPPER	.450-03	<	.416-04
IRON	.165		.161-01
LEAD	.150-03	<	.104-03
MANGANESE	.270-02		.333-03
MERCURY	.000	*	.000
MOLYBDENUM	.750-05	<	.104-04
NICKEL	.975-04	<	.364-04
SELENIUM	.105-04		.520-05
TELLURIUM	.525-05	<	.520-05
THALLIUM	.300-03	<	.312-03
TIN	.495-04	<	.104-04
TITANIUM	.180-01		.166-02
URANIUM	.000	*	.000
VANADIUM	.150-03	<	.156-03
ZINC	.293-03	<	.156-04
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	.281-03	<	.217-03
FLUORIDE	.421-03		.192-03
CYANIDE	.747-04	<	.175-04
NITRATE	.120-05	<	.988-02
SULFATE	.000	*	.000
AMMONIUM	.680-04		.612-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASLINE	LOW NOX
ANTIMONY	< .201-05	< .252-06
ARSENIC	.343-04	.467-05
BARIUM	.625-03	.647-04
BERYLLIUM	.606-05	.791-06
BISMUTH	< .141-03	< .144-04
BORON	< .101-04	< .288-05
CADMIUM	< .403-05	< .360-06
CHROMIUM	.705-04	.306-04
COBALT	.343-04	.288-05
COPPER	.302-03	.227-04
IRON	.725-01	.755-02
LEAD	.604-04	.719-05
MANGANESE	.123-02	.119-03
MERCURY	* .000	* .000
MOLYBDENUM	.383-04	.683-05
NICKEL	.584-04	.209-04
SELENIUM	.463-05	.212-05
TELLURIUM	< .201-05	< .324-06
THALLIUM	< .181-03	< .180-04
TIN	.524-04	.144-05
TITANIUM	.967-02	.104-02
URANIUM	* .000	* .000
VANADIUM	< .606-04	< .719-05
ZINC	.282-03	.216-04
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	< .285-03	< .177-04
FLUORIDE	.354-03	.162-04
CYANIDE	< .230-04	< .142-05
NITRATE	.127-05	.230-02
SULFATE	* .000	* .000
AMMONIUM	.598-04	.442-05

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCB/JOULE)- BOILER OUTLET
1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS		BASELINE	
ANTIMONY	<	.173-05	<
ARSENIC	*	.000	.272-06
BARIUM		.112-03	.240-07
BERYLLIUM		.145-05	.256-04
BISMUTH		.741-06	.400-06
BORON	*	.000	.112-06
CADMIUM		.329-05	.160-03
CHROMIUM		.176-04	.232-06
COBALT		.102-04	.288-04
COPPER		.823-04	.184-05
IRON		.129-01	.152-04
LEAD		.466-04	.208-02
MANGANESE		.274-03	.720-05
MERCURY	*	.000	.424-04
MOLYBDENUM		.274-05	.136-07
NICKEL		.154-03	.400-06
SELENIUM	*	.000	.224-04
TELLURIUM		.164-05	.880-06
THALLIUM		.494-06	.240-06
TIN		.547-08	.720-07
TITANIUM		.357-02	.600-09
URANIUM	*	.000	<
VANADIUM		.796-04	.592-03
ZINC	*	.796-04	.000
ZIRCONIUM	*	.000	.136-04
ANIONS			.104-04
CHLORIDE	*	.000	.000
FLUORIDE	*	.000	.000
CYANIDE	*	.000	.000
NITRATE	*	.000	.000
SULFATE	*	.000	.000
AMMONIUM	*	.000	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)-
BOILER OUTLET
FILTER

TRACE ELEMENTS	TEST CONDITION		
CATIONS	BASELINE	LOW NOX	
ANTIMONY	< .271-06	< .285-06	
ARSENIC	.149-05	.349-06	
BARIUM	.249-03	.281-04	
BERYLLIUM	< .489-07	< .919-08	
BISMUTH	.148-05	.138-06	
BORON	.107-03	.793-04	
CADMIUM	.120-04	.873-06	
CHROMIUM	.149-04	.297-04	
COBALT	.489-07	.133-05	
COPPER	.102-03	.970-05	
IRON	.271-02	.113-02	
LEAD	.105-03	.102-05	
MANGANESE	.731-04	.256-04	
MERCURY	.960-07	.708-07	
MOLYBDENUM	< .489-07	.313-07	
NICKEL	.168-04	.212-04	
SELENIUM	.139-04	.965-06	
TELLURIUM	.290-05	.221-07	
THALLIUM	.489-07	.414-07	
TIN	< .873-09	.184-08	
TITANIUM	.602-03	.248-03	
URANIUM	.000	.000	*
VANADIUM	.163-04	.512-05	
ZINC	.489-06	.200-04	
ZIRCONIUM	.000	.000	*
ANIONS			
CHLORIDE	.000	.000	*
FLUORIDE	.000	.000	*
CYANIDE	.000	.000	*
NITRATE	.000	.000	*
SULFATE	.000	.000	*
AMMONIUM	.000	.000	*

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET

XAD-2 CARTRIDGE

TRACE ELEMENTS		TEST CONDITION		LOW NOX
CATIONS		BASELINE		
ANTIMONY	<	.131-05	<	.165-05
ARSENIC	<	.197-05	<	.220-05
BARIUM	<	.329-06	<	.441-06
BERYLLIUM	<	.657-07	<	.551-07
BISMUTH	<	.263-05	<	.276-05
BORON		.756-04		.231-03
CADMIUM	<	.657-05	<	.551-05
CHROMIUM	<	.329-06	<	.661-06
COBALT	<	.263-04	<	.276-04
COPPER	<	.230-04	<	.276-04
IRON	<	.230-04	<	.220-04
LEAD	<	.986-04	<	.110-03
MANGANESE	<	.131-04	<	.386-04
MERCURY	*	.000	*	.000
MOLYBDENUM	<	.329-05	<	.386-05
NICKEL	<	.230-04	<	.276-04
SELENIUM	<	.167-05	<	.165-05
TELLURIUM	<	.296-05	<	.331-05
THALLIUM	<	.197-03	<	.220-03
TIN	<	.167-05	<	.165-05
TITANIUM	<	.296-05	<	.331-05
URANIUM	*	.000	*	.000
VANADIUM	<	.329-05	<	.331-05
ZINC	<	.986-05	<	.110-04
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- BOILER OUTLET
FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASLINE	LOW NOX
ANTIMONY	< .120-06	< .151-06
ARSENIC	< .956-06	.121-05
BARIUM	< .283-07	< .335-07
BERYLLIUM	< .708-08	< .418-08
BISMUTH	< .181-06	< .251-06
BORON	< .460-03	< .837-05
CADMIUM	< .297-06	< .460-06
CHROMIUM	< .191-05	.753-05
COBALT	< .181-05	< .201-05
COPPER	.743-05	.251-05
IRON	.347-04	.418-04
LEAD	< .602-05	< .100-04
MANGANESE	.209-05	.502-05
MERCURY	< .283-07	< .377-07
MOLYBDENUM	.387-05	.192-05
NICKEL	.145-04	.130-04
SELENIUM	.237-04	.201-04
TELLURIUM	< .241-06	< .301-06
THALLIUM	< .149-04	< .201-04
TIN	.297-05	.201-05
TITANIUM	< .241-06	< .301-06
URANIUM	* .000	* .000
VANADIUM	< .120-06	< .151-06
ZINC	.708-05	.180-04
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCg/JOULE) - BOILER OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< .115-06	<	.204-06
ARSENIC	< .765-07	<	.136-06
BARIUM	* .000	*	.000
BERYLLIUM	* .000	*	.000
BISMUTH	* .000	*	.000
BORON	* .000	*	.000
CADMIUM	* .000	*	.000
CHROMIUM	* .000	*	.000
COBALT	* .000	*	.000
COPPER	* .000	*	.000
IRON	* .000	*	.000
LEAD	* .000	*	.000
MANGANESE	* .000	*	.000
MERCURY	< .153-06	<	.272-06
MOLYBDENUM	* .000	*	.000
NICKEL	* .000	*	.000
SELENIUM	* .000	*	.000
TELLURIUM	* .000	*	.000
THALLIUM	* .000	*	.000
TIN	* .000	*	.000
TITANIUM	* .000	*	.000
URANIUM	* .000	*	.000
VANADIUM	* .000	*	.000
ZINC	* .000	*	.000
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	* .000	*	.000
FLUORIDE	* .000	*	.000
CYANIDE	* .000	*	.000
NITRATE	* .000	*	.000
SULFATE	* .000	*	.000
AMMONIUM	* .000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MC6/JOULE)- BOILER OUTLET

TRACE ELEMENTS	TEST CONDITION	
	CATIONS	LOW NOX
ANTIMONY ARSENIC BARIUM BERYLLIUM BISMUTH	< .101-04	< .698-05
	< .530-04	< .294-04
	< .113-02	< .145-03
	< .246-04	< .266-05
BORON CADMIUM CHROMIUM COBALT COPPER	< .446-03	< .278-03
	< .691-03	< .503-03
	< .337-04	< .126-04
	< .278-03	< .122-03
IRON LEAD MANGANESE MERCURY MOLYBDENUM	< .110-03	< .720-04
	< .967-03	< .119-03
	< .253	< .269-01
	< .466-03	< .240-03
NICKEL SELENIUM TELLURIUM THALLIUM TIN	< .429-02	< .563-03
	< .277-06	< .394-06
	< .558-04	< .234-04
	< .364-03	< .141-03
TITANIUM URANIUM VANADIUM ZINC ZIRCONIUM	< .544-04	< .309-04
	< .152-04	< .939-05
	< .694-03	< .571-03
	< .107-03	< .155-04
ANIONS CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE AMMONIUM	* .318-01	* .355-02
	* .000	* .000
	< .330-03	< .185-03
	* .672-03	* .966-04
CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE AMMONIUM	* .000	* .000
	< .566-03	< .235-03
	< .775-03	< .209-03
	< .977-04	< .189-04
NITRATE SULFATE AMMONIUM	< .254-05	< .122-01
	* .000	* .000
	< .128-03	< .657-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MC6/JOULE) - ESP HOPPER ASH

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASLINE		
ANTIMONY	.249-05		.166-05
ARSENIC	.208-04		.121-04
BARIUM	.695-04		.446-04
BERYLLIUM	.283-05		.153-05
BISMUTH	.232-04	<	.128-04
BORON	.232-05	<	.128-05
CADMIUM	.579-06	<	.956-06
CHROMIUM	.156-04		.108-04
COBALT	.156-04		.670-05
COPPER	.695-04		.446-04
IRON	.150-01		.765-02
LEAD	.637-04		.383-04
MANGANESE	.318-03		.159-03
MERCURY	.000	*	.000
MOLYBDENUM	.405-05		.255-05
NICKEL	.307-04		.159-04
SELENIUM	.318-05		.217-05
TELLURIUM	.463-06	<	.255-06
THALLIUM	.289-04	<	.159-04
TIN	.463-05		.255-05
TITANIUM	.232-02		.115-02
URANIUM	.000	*	.000
VANADIUM	.174-04		.112-04
ZINC	.203-03		.124-03
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	.225-04	<	.109-04
FLUORIDE	.399-05		.484-05
CYANIDE	.181-05	<	.680-06
NITRATE	.573-02		.998-02
SULFATE	.130-03		.265-04
AMMONIUM	.161-04		.156-04

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCg/JOULE) - ESP OUTLET

10 MICRON CYCLONE

TRACE ELEMENTS		TEST CONDITION		LOW NOX
CATIONS		BASLINE		
ANTIMONY	<	.74-08	<	.358-08
ARSENIC	*	.000	<	.239-07
BARIUM	<	.790-05	<	.299-07
BERYLLIUM	<	.105-08	<	.281-08
BISMUTH	<	.102-07	<	.239-06
BORON	<	.120-07	*	.000
CADMIUM	<	.270-06	<	.597-08
CHROMIUM	<	.74-06	<	.311-07
COBALT	<	.105-08	<	.358-07
COPPER	<	.928-06	<	.478-07
IRON		.671-04		.227-04
LEAD		.250-05	<	.119-06
MANGANESE		.17-05	<	.484-06
MERCURY	*	.000	<	.119-09
MOLYBDENUM		.163-06	<	.119-07
NICKEL		.657-06	<	.418-07
SELENIUM	*	.000	<	.597-08
TELLURIUM		.321-07	<	.537-08
THALLIUM		.105-07	<	.358-06
TIN		.718-10	<	.119-07
TITANIUM		.223-08		.257-05
URANIUM	*	.000	*	.000
VANADIUM		.344-06	<	.119-06
ZINC		.359-05	<	.179-07
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT ANALYSIS - (MCU/JOULE)-
3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	LOW NOX
CATIONS	BASELINE	
ANTIMONY	< .821-08	< .192-07
ARSENIC	* .000	* .000
BARIUM	< .874-05	< .118-06
BERYLLIUM	< .117-08	< .596-09
BISMUTH	* .117-07	* .196-07
BORON	* .000	* .000
CADMIUM	* .299-06	* .860-07
CHROMIUM	< .821-06	< .403-05
COBALT	* .117-08	* .136-06
COPPER	* .103-05	* .246-05
IRON	* .742-04	* .136-03
LEAD	* .276-05	* .729-06
MANGANESE	* .193-05	* .311-05
MERCURY	* .000	* .000
MOLYBDENUM	* .187-06	* .775-07
NICKEL	* .728-06	* .433-05
SELENIUM	* .000	* .000
TELLURIUM	* .355-07	* .183-07
THALLIUM	* .117-07	* .554-08
TIN	* .794-10	* .852-10
TITANIUM	* .246-08	* .290-04
URANIUM	* .000	* .000
VANADIUM	* .380-06	* .338-06
ZINC	* .397-05	* .132-05
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT ANALYSIS - (MC6/JOULE)-
1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	< .175-07	< .290-07
ARSENIC	* .000	* .000
BARIUM	.186-04	.160-04
BERYLLIUM	< .248-08	< .243-08
BISMUTH	.254-07	.187-06
BORON	* .000	* .000
CADMIUM	.636-06	.569-06
CHROMIUM	.175-05	.197-04
COBALT	.248-08	.666-06
COPPER	.219-05	.633-05
IRON	.158-03	.318-03
LEAD	.588-05	.603-05
MANGANESE	.412-05	.100-04
MERCURY	* .000	* .000
MOLYBDENUM	.398-06	.520-06
NICKEL	.155-05	.186-04
SELENIUM	* .000	* .000
TELLURIUM	.756-07	.402-07
THALLIUM	.248-07	.537-07
TIN	.169-09	.187-09
TITANIUM	.525-08	.111-03
URANIUM	* .000	* .000
VANADIUM	.810-06	.234-05
ZINC	.846-05	.309-05
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE) - ESP OUTLET

FILTER

TRACE ELEMENTS CATIONS	TEST CONDITION		LOW NOX
	BASELINE		
ANTIMONY	<	.871-08	<
ARSENIC	*	.000	*
BARIUM		.927-05	.824-05
BERYLLIUM	<	.124-08	<
BISMUTH		.126-07	.966-07
BORON	*	.000	*
CADMIUM		.317-06	.294-06
CHROMIUM		.871-06	.102-04
COBALT	<	.12-08	.344-06
COPPER		.109-05	.327-05
IRON		.787-04	.164-03
LEAD		.293-05	.312-05
MANGANESE		.205-05	.518-05
MERCURY	*	.000	.000
MOLYBDENUM		.198-06	.269-06
NICKEL		.770-06	.962-05
SELENIUM	*	.000	.000
TELLURIUM		.376-07	.208-07
THALLIUM		.124-07	.174-07
TIN		.843-10	.966-10
TITANIUM		.261-08	.575-04
URANIUM	*	.000	.000
VANADIUM		.403-06	.121-05
ZINC		.421-05	.159-05
ZIRCONIUM	*	.000	.000
ANIONS			
CHLORIDE	*	.000	.000
FLUORIDE	*	.000	.000
CYANIDE	*	.000	.000
NITRATE	*	.000	.000
SULFATE	*	.000	.000
AMMONIUM	*	.000	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE)- ESP OUTLET
XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION	
	BASELINE	LOW NOX
CATIONS		
ANTHONY	<	<
ARSENIC	<	<
BARIUM	<	<
BERYLLIUM	<	<
BISMUTH	<	<
BORON	<	<
CADMIUM	<	<
CHROMIUM	<	<
COBALT	<	<
COPPER	<	<
IRON	<	<
LEAD	<	<
MANGANESE	<	<
MERCURY	<	<
MOLYBDENUM	<	<
NICKEL	<	<
SELENIUM	<	<
TELLURIUM	<	<
THALLIUM	<	<
TIN	<	<
TITANIUM	<	<
URANIUM	<	<
VANADIUM	<	<
ZINC	<	<
ZIRCONIUM	<	<
ANIONS		
CHLORIDE	*	*
FLUORIDE	*	*
CYANIDE	*	*
NITRATE	*	*
SULFATE	*	*
AMMONIUM	*	*

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT ANALYSIS - (MCG/JOULE)-
FIRST IMPINGERS

TRACE ELEMENTS CATIONS	TEST CONDITION		LOW NOX
	BASLINE		
ANTIMONY	< .837-07	<	.858-07
ARSENIC	.118-05		.124-05
BARIUM	.837-07		.217-06
BERYLLIUM	< .310-08	<	.252-08
BISMUTH	< .170-06	<	.129-06
BORON	.341-03		.454-04
CADMIUM	< .434-06	<	.217-06
CHROMIUM	.211-05		.303-05
COBALT	< .170-05	<	.129-05
COPPER	< .147-05		.530-05
IRON	.961-05		.984-05
LEAD	< .620-05	<	.429-05
MANGANESE	.170-05		.984-06
MERCURY	< .217-07	<	.227-07
MOLYBDENUM	.189-06		.732-06
NICKEL	.211-05		.252-05
SELENIUM	.118-04		.154-04
TELLURIUM	< .211-06	<	.174-06
THALLIUM	< .127-04	<	.108-04
TIN	.310-05		.217-05
TITANIUM	< .211-06	<	.174-06
URANIUM	* .000	*	.000
VANADIUM	< .105-06	<	.858-07
ZINC	.105-05		.151-05
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	* .000	*	.000
FLUORIDE	* .000	*	.000
CYANIDE	* .000	*	.000
NITRATE	* .000	*	.000
SULFATE	* .000	*	.000
AMMONIUM	* .000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE) - ESP OUTLET

2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS		BASELINE	
ANTHONY	<	.103-06	<
ARSENIC	<	.103-06	<
BARIUM	*	.000	*
BERYLLIUM	*	.000	*
BISMUTH	*	.000	*
BORON	*	.000	*
CADMIUM	*	.000	*
CHROMIUM	*	.000	*
COBALT	*	.000	*
COPPER	*	.000	*
IRON	*	.000	*
LEAD	*	.000	*
MANGANESE	*	.000	*
MERCURY	<	.137-06	<
MOLYBDENUM	*	.000	*
NICKEL	*	.000	*
SELENIUM	*	.000	*
TELLURIUM	*	.000	*
THALLIUM	*	.000	*
TIN	*	.000	*
TITANIUM	*	.000	*
URANIUM	*	.000	*
VANADIUM	*	.000	*
ZINC	*	.000	*
ZIRCONIUM	*	.000	*
ANIONS			
CHLORIDE	*	.000	*
FLUORIDE	*	.000	*
CYANIDE	*	.000	*
NITRATE	*	.000	*
SULFATE	*	.000	*
AMMONIUM	*	.000	*

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/JOULE) - ESP OUTLET

TRACE ELEMENTS		TEST CONDITION		LOW NOX
CATIONS	BASELINE			
ANTIMONY	< .721-05	<		< .121-05
ARSENIC	< .130-05	<		< .292-05
BARIUM	< .158-03	<		< .248-04
BERYLLIUM	< .141-05	<		< .334-07
BISMUTH	< .907-05	<		< .234-05
BORON	< .344-03	<		< .122-03
CADMIUM	< .247-05	<		< .594-05
CHROMIUM	< .657-05	<		< .515-04
COBALT	< .343-05	<		< .168-04
COPPER	< .765-05	<		< .317-04
IRON	< .406-03	<		< .679-03
LEAD	< .214-04	<		< .619-04
MANGANESE	< .119-04	<		< .269-04
MERCURY	< .275-06	<		< .159-06
MOLYBDENUM	< .379-05	<		< .280-05
NICKEL	< .128-04	<		< .494-04
SELENIUM	< .124-04	<		< .163-04
TELLURIUM	< .415-06	<		< .193-05
THALLIUM	< .128-04	<		< .130-03
TIN	< .312-05	<		< .760-04
TITANIUM	< .456-06	<		< .202-03
URANIUM	< .000	*		< .000
VANADIUM	< .228-05	<		< .600-05
ZINC	< .234-04	<		< .123-04
ZIRCONIUM	< .000	*		< .000
ANIONS				
CHLORIDE	< .000	*		< .000
FLUORIDE	< .000	*		< .000
CYANIDE	< .000	*		< .000
NITRATE	< .000	*		< .000
SULFATE	< .000	*		< .000
AMMONIUM	< .000	*		< .000

APPENDIX D-3
TRACE ELEMENT FLOW RATES
(micrograms per dry standard cubic meter)

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET
10 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION	
	BASELINE	LOW NOX
CATIONS		
ANTIMONY	< 11.7	< 10.9
ARSENIC	39.1	54.6
BARIUM	391.	< 68.2
BERYLLIUM	39.1	3.68
BISMUTH	< 782.	< 682.
BORON	< 97.8	< 54.6
CADMIUM	< 19.6	< 13.6
CHROMIUM	450.	65.5
COBALT	< 97.8	< 95.5
COPPER	.11/+04	< 109.
IRON	.430+06	.423+05
LEAD	< 391.	< 273.
MANGANESE	.704+04	873.
MERCURY	* .000	* .000
MOLYBDENUM	< 19.6	< 27.3
NICKEL	254.	< 95.5
SELENIUM	27.4	13.6
TELLURIUM	< 13.7	< 13.6
THALLIUM	< 782.	< 819.
TIN	129.	< 27.3
TITANIUM	.469+05	.437+04
URANIUM	* .000	* .000
VANADIUM	< 391.	< 409.
ZINC	763.	< 40.9
ZIRCONIUM	* .000	* .000
ANIONS		
CHLORIDE	< 732.	< 570.
FLUORIDE	.110+04	505.
CYANIDE	195.	< 46.0
NITRATE	3.32	.259+05
SULFATE	* .000	* .000
AMMONIUM	177.	161.

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

3 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< 5.25	<	.661
ARSENIC	89.3		12.3
BARIUM	.163+04		170.
BERYLLIUM	21.0		2.08
BISMUTH	< 368.	<	37.7
BORON	< 26.3	<	7.55
CADMIUM	< 10.5	<	.944
CHROMIUM	184.		40.2
COBALT	89.3		7.55
COPPER	788.		59.5
IRON	.189+06		.198+05
LEAD	< 158.	<	18.9
MANGANESE	.320+04		311.
MERCURY	* .000	*	.000
MOLYBDENUM	99.8		17.9
NICKEL	152.		54.7
SELENIUM	12.1		5.57
TELLURIUM	< 5.25	<	.849
THALLIUM	< 473.	<	47.2
TIN	137.		3.77
TITANIUM	.252+05		.274+04
URANIUM	* .000	*	.000
VANADIUM	< 210.	<	18.9
ZINC	735.		56.6
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	< 743.	<	46.4
FLUORIDE	923.		42.6
CYANIDE	< 59.9	<	3.74
NITRATE	3.31		.604+04
SULFATE	* .000	*	.000
AMMONIUM	156.		11.6

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET
1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< 4.51	<	.714
ARSENIC	* .000		.630-01
BARIUM	293.		67.2
BERYLLIUM	3.79		1.05
BISMUTH	1.92	<	.294
BORON	* .000		420.
CADMIUM	8.58		.609
CHROMIUM	45.8		75.6
COBALT	26.5		4.83
COPPER	215.		39.9
IRON	.336+05		.546+04
LEAD	122.		18.9
MANGANESE	715.		111.
MERCURY	* .000		.357-01
MOLYBDENUM	7.15		1.05
NICKEL	400.		58.8
SELENIUM	* .000		2.31
TELLURIUM	4.79		.630
THALLIUM	1.29		.189
TIN	.143-01	<	.210-02
TITANIUM	.930+04		.155+04
URANIUM	* .000	*	.000
VANADIUM	207.		35.7
ZINC	207.		27.3
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	* .000	*	.000
FLUORIDE	* .000	*	.000
CYANIDE	* .000	*	.000
NITRATE	* .000	*	.000
SULFATE	* .000	*	.000
AMMONIUM	* .000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MC6/DSCH) - BOILER OUTLET
FILTER

TRACE ELEMENTS	TEST CONDITION	
	CATIONS	LOW NOX
ANTIMONY ARSENIC BARIUM BERYLLIUM BISMUTH	< .706	< .748
	3.89	.917
	637.	73.7
	< .127	< .241-01
BORON CADMIUM CHROMIUM COBALT COPPER	3.85	.362
	280.	208.
	31.4	2.29
	38.8	78.0
IRON LEAD MANGANESE MERCURY MOLYBDENUM	< .127	3.50
	265.	25.5
	.706+04	.297+04
	273.	2.68
NICKEL SELENIUM TELLURIUM THALLIUM TIN	191.	67.3
	.250	.186
	< .127	.821-01
	43.1	55.7
TITANIUM URANIUM VANADIUM ZINC ZIRCONIUM	36.2	2.53
	7.56	.579-01
	< .127	.109
	< .228-02	.483-02
ANIONS CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE AMMONIUM	.157+04	652.
	.000	.000
	42.4	13.4
	< 1.27	52.6
	* .000	* .000
	* .000	* .000
	* .000	* .000
	* .000	* .000
	* .000	* .000
	* .000	* .000
	* .000	* .000
	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MC6/DSCM) - BOILER OUTLET
XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< 3.43	<	4.34
ARSENIC	< 5.14	<	5.79
BARIUM	< .857	<	1.16
BERYLLIUM	< .171	<	.145
BISMUTH	< 6.89	<	7.23
BORON	197.		608.
CADMIUM	< 17.1	<	14.5
CHROMIUM	< .857	<	1.74
COBALT	< 68.5	<	72.3
COPPER	< 60.0	<	72.3
IRON	< 60.0	<	57.9
LEAD	< 257.	<	289.
MANGANESE	< 34.9	<	101.
MERCURY	* .000	*	.000
MOLYBDENUM	< 8.57	<	10.1
NICKEL	< 60.0	<	72.3
SELENIUM	< 4.28	<	4.34
TELLURIUM	< 7.71	<	8.68
THALLIUM	< 514.	<	579.
TIN	< 4.28	<	4.34
TITANIUM	< 7.71	<	8.68
URANIUM	* .000	*	.000
VANADIUM	< 8.57	<	8.68
ZINC	< 25.7	<	28.9
ZIRCONIUM	* .000	*	.000
ANIONS			
CHLORIDE	* .000	*	.000
FLUORIDE	* .000	*	.000
CYANIDE	* .000	*	.000
NITRATE	* .000	*	.000
SULFATE	* .000	*	.000
AMMONIUM	* .000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MC6/USCM) - BOILER OUTLET
FIRST IMPINGERS

TRACE ELEMENTS	TEST CONDITION	
CATIONS	BASELINE	LOW NOX
ANTIMONY	< .314	< .395
ARSENIC	< 2.49	< 3.18
BARIUM	< .738-01	< .878-01
BERYLLIUM	< .165-01	< .110-01
BISMUTH	< .471	< .659
BORON	< .120+04	< 22.0
CADMIUM	< .775	< 1.21
CHROMIUM	< 4.98	< 19.8
COBALT	< 4.71	< 5.27
COPPER	< 19.4	< 6.59
IRON	< 90.4	< 110.
LEAD	< 15.7	< 26.4
MANGANESE	< 5.44	< 13.2
MERCURY	< .738-01	< .988-01
MOLYBDENUM	< 10.1	< 5.05
NICKEL	< 37.8	< 34.0
SELENIUM	< 61.8	< 52.7
TELLURIUM	< .627	< .791
THALLIUM	< 38.6	< 52.7
TIN	< 7.75	< 5.27
TITANIUM	< .627	< .791
URANIUM	< .000	< .000
VANADIUM	< .314	< .395
ZINC	< 18.5	< 47.2
ZIRCONIUM	< .000	< .000
ANIONS		
CHLORIDE	* .000	* .000
FLUORIDE	* .000	* .000
CYANIDE	* .000	* .000
NITRATE	* .000	* .000
SULFATE	* .000	* .000
AMMONIUM	* .000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET
2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
	CATIONS	BASELINE	
ANTIMONY	<	.299	<
	<	.199	<
	*	.000	*
	*	.000	*
	*	.000	*
BORON	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
IRON	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	<	.399	<
MOLYBDENUM	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
NICKEL	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
TITANIUM	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
ZINC	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
ANIONS	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
AMMONIUM	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - BOILER OUTLET

TRACE ELEMENTS	TEST CONDITION	
	CATIONS	LOW NOX
ANTHONY	< 26.2	< 18.3
	140.	77.2
	.295+04	< 380.
	64.2	6.99
BERYLLIUM	< .118+04	< 728.
BISMUTH	< .180+04	< .132+04
	< 88.0	< 53.2
BORON	724.	321.
	< 287.	< 189.
CADMIUM	.252+04	< 313.
CHROMIUM	.660+06	.707+05
	< .122+04	< 629.
COBALT	.112+05	.148+04
	.725	1.03
COPPER	< 145.	< 61.5
IRON	948.	< 371.
	142.	61.1
LEAD	< 39.6	< 24.7
	< .181+04	< .150+04
MANGANESE	278.	< 40.7
MERCURY	.830+05	.932+04
	* .000	* .000
MOLYBDENUM	< 860.	< 486.
	* .175+04	< 254.
NICKEL	* .000	* .000
SELENIUM	< .148+04	< 616.
	< 202+04	548.
TELLURIUM	255.	< 49.7
	6.63	< .320+05
THALLIUM	* .000	* .000
TIN	333.	172.
TITANIUM		
URANIUM		
VANADIUM		
ZINC		
ZIRCONIUM		
ANIONS		
CHLORIDE		
FLUORIDE		
CYANIDE		
NITRATE		
SULFATE		
AMMONIUM		

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT ANALYSIS - (MCG/DSCM) -

10 MICRON CYCLONE

TRACE ELEMENTS CATIONS	TEST CONDITION		LOW NOX
		BASELINE	
ANTIMONY	<	.199-01	< .103-01
ARSENIC	*	.000	< .686-01
BARIUM		21.2	< .857-01
BERYLLIUM	<	.282-02	< .806-02
BISMUTH		.289-01	< .686
BORON			
CADMIUM	<	.321-01	* .000
CHROMIUM		.723	< .171-01
COBALT		1.99	< .892-01
COPPER	<	.282-02	< .103
		2.46	< .137
IRON			
LEAD		180.	65.2
MANGANESE		6.69	.343
MERCURY		4.68	1.39
MOLYBDENUM	*	.000	< .343-03
		.452	< .343-01
NICKEL			
SELENIUM		1.76	< .120
TELLURIUM	*	.000	< .171-01
THALLIUM		.857-01	< .154-01
TIN		.282-01	< 1.03
		.192-03	< .343-01
TITANIUM			
URANIUM		.596-02	7.37
VANADIUM	*	.000	* .000
ZINC		.921	< .343
ZIRCONIUM	*	9.62	< .514-01
		.000	* .000
ANIONS			
CHLORIDE	*	.000	* .000
FLUORIDE	*	.000	* .000
CYANIDE	*	.000	* .000
NITRATE	*	.000	* .000
SULFATE	*	.000	* .000
AMMONIUM	*	.000	* .000

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT ANALYSIS - (MCG/DSCH) -
3 MICRON CYCLONE

TRACE ELEMENTS		TEST CONDITION		LOW NOX
CATIONS		BASELINE		
ANTIMONY	<	.220-01	<	.550-01
ARSENIC	*	.000	*	.000
BARIUM		23.4		.340
BERYLLIUM	<	.312-02	<	.171-02
BISMUTH		.319-01		.562-01
BORON	*	.000	*	.000
CADMIUM		.600		.247
CHROMIUM		2.20		11.6
COBALT	<	.312-02		.391
COPPER		2.75		7.06
IRON		199.		.991.
LEAD		7.40		2.09
MANGANESE		5.18		8.92
MERCURY	*	.000	*	.000
MOLYBDENUM		.500		.223
NICKEL		1.94		12.4
SELENIUM	*	.000	*	.000
TELLURIUM		.550-01		.526-01
THALLIUM		.312-01		.159-01
TIN		.213-03		.245-03
TITANIUM		.660-02		83.1
URANIUM	*	.000	*	.000
VANADIUM		1.02		.971
ZINC	*	10.6	*	5.78
ZIRCONIUM		.000		.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - ESP OUTLET

1 MICRON CYCLONE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
CATIONS	BASELINE		
ANTIMONY	< .468-01	<	.832-01
ARSENIC	.000	*	.000
BARIUM	49.9		45.8
BERYLLIUM	.665-02	<	.698-02
BISMUTH	.680-01		.537
BORON	.000	*	.000
CADMIUM	1.70		1.63
CHROMIUM	4.64		56.6
COBALT	.665-02	<	1.91
COPPER	5.85		18.2
IRON	423.		913.
LEAD	15.8		17.3
MANGANESE	11.0		28.8
MERCURY	.000	*	.000
MOLYBDENUM	1.07		1.49
NICKEL	4.14		53.4
SELENIUM	.000	*	.000
TELLURIUM	.202		.115
THALLIUM	.665-01		.966-01
TIN	.453-03		.537-03
TITANIUM	.141-01		319.
URANIUM	.000	*	.000
VANADIUM	2.17		6.71
ZINC	22.7		8.86
ZIRCONIUM	.000	*	.000
ANIONS			
CHLORIDE	.000	*	.000
FLUORIDE	.000	*	.000
CYANIDE	.000	*	.000
NITRATE	.000	*	.000
SULFATE	.000	*	.000
AMMONIUM	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - ESP OUTLET

FILTER

TRACE ELEMENTS CATIONS	TEST CONDITION		LOW NOX
		BASELINE	
ANTIMONY	<	.233-01	< .430-01
ARSENIC	*	.000	* .000
BARIUM		24.8	23.7
BERYLLIUM	<	.331-02	< .361-02
BISMUTH		.339-01	.277
BORON	*	.000	* .000
CADMIUM		.849	.844
CHROMIUM		2.33	29.2
COBALT	<	.331-02	.987
COPPER		2.91	9.39
IRON		211.	471.
LEAD		7.65	8.95
MANGANESE		5.49	14.9
MERCURY	*	.000	* .000
MOLYBDENUM		.530	.771
NICKEL		2.00	27.6
SELENIUM	*	.000	* .000
TELLURIUM		.101	.596-01
THALLIUM		.331-01	.499-01
TIN		.226-03	.277-03
TITANIUM		.700-02	165.
URANIUM	*	.000	* .000
VANADIUM		1.08	3.47
ZINC		11.3	4.58
ZIRCONIUM	*	.000	* .000
ANIONS			
CHLORIDE	*	.000	* .000
FLUORIDE	*	.000	* .000
CYANIDE	*	.000	* .000
NITRATE	*	.000	* .000
SULFATE	*	.000	* .000
AMMONIUM	*	.000	* .000

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - ESP OUTLET
XAD-2 CARTRIDGE

TRACE ELEMENTS	TEST CONDITION		LOW NOX
	CATIONS	BASELINE	
ANTIMONY ARSENIC BARIUM BERYLLIUM BISMUTH	<	18.7	<
	<	.623-01	<
	<	304.	<
	<	3.74	<
	<	23.7	<
BORON CADMIUM CHROMIUM COBALT COPPER	<	7.48	219.
	<	1.37	13.7
	<	.748	41.7
	<	4.61	41.0
	<	2.49	41.0
IRON LEAD MANGANESE MERCURY MOLYBDENUM	<	50.5	82.1
	<	3.12	137.
	<	.873	20.5
	<	.312	* .000
	<	7.10	<
NICKEL SELENIUM TELLURIUM THALLIUM TIN	<	18.7	41.0
	<	1.68	<
	<	.623-01	<
	<	.623-01	4.79
	<	.623-01	212.
TITANIUM URANIUM VANADIUM ZINC ZIRCONIUM	<	.623	4.79
	*	.000	* .000
	<	.623	5.47
	*	5.61	13.7
	*	.000	* .000
ANIONS CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE	*	.000	* .000
	*	.000	* .000
	*	.000	* .000
	*	.000	* .000
	*	.000	* .000
AMMONIUM	*	.000	* .000

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT ANALYSIS - (MCG/DSCM) -

FIRST IMPINGERS

TRACE ELEMENTS		TEST CONDITION		LOW NOX
CATIONS		BASELINE		
ANTIMONY	<	.224	<	.246
ARSENIC		3.15		3.55
BARIUM		.224		.623
BERYLLIUM	<	.830-02	<	.724-02
BISMUTH	<	.457	<	.369
BORON		913.		130.
CADMIUM	<	1.16	<	.623
CHROMIUM		5.64		8.69
COBALT	<	4.57	<	3.69
COPPER	<	3.98		15.2
IRON		25.7		28.2
LEAD	<	16.8	<	12.3
MANGANESE		4.57		2.82
MERCURY	<	.581-01	<	.652-01
MOLYBDENUM		.506		2.10
NICKEL		5.64		7.24
SELENIUM		31.5		44.2
TELLURIUM	<	.564	<	.500
THALLIUM	<	34.0	<	31.1
TIN		8.30		6.23
TITANIUM	<	.564	<	.500
URANIUM	*	.000	*	.000
VANADIUM	<	.282	<	.246
ZINC		2.82		4.35
ZIRCONIUM	*	.000	*	.000
ANIONS				
CHLORIDE	*	.000	*	.000
FLUORIDE	*	.000	*	.000
CYANIDE	*	.000	*	.000
NITRATE	*	.000	*	.000
SULFATE	*	.000	*	.000
AMMONIUM	*	.000	*	.000

SPREADER STOKER INDUSTRIAL BOILER ESP OUTLET
TRACE ELEMENT ANALYSIS - (MCG/OSCH) -
2ND & 3RD IMPINGERS

TRACE ELEMENTS	TEST CONDITION		LOW NOX
	CATIONS	BASELINE	
ANTIMONY ARSENIC BARIUM BERYLLIUM BISMUTH	<	.275	<
	<	.275	<
	*	.000	*
	*	.000	*
	*	.000	*
BORON CADMIUM CHROMIUM COBALT COPPER	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
IRON LEAD MANGANESE MERCURY MOLYBDENUM	*	.000	*
	*	.000	*
	*	.000	*
	<	.367	<
	*	.000	*
NICKEL SELENIUM TELLURIUM THALLIUM TIN	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
TITANIUM URANIUM VANADIUM ZINC ZIRCONIUM	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
ANIONS CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
	*	.000	*
AMMONIUM	*	.000	*

SPREADER STOKER INDUSTRIAL BOILER
TRACE ELEMENT ANALYSIS - (MCG/DSCM) - ESP OUTLET

TRACE ELEMENTS	TEST CONDITION	
	CATIONS	LOW NOX
ANTIMONY ARSENIC BARIUM BERYLLIUM BISMUTH	< 19.3	< 5.47
	< 3.49	< 7.23
	424.	< 71.2
	< 3.76	.960-01
	24.3	< 6.71
BORON CADMIUM CHROMIUM COBALT COPPER	< 921.	349.
	6.61	17.0
	17.6	146.
	< 9.19	48.1
	20.5	< 91.0
IRON LEAD MANGANESE MERCURY MOLYBDENUM	.109+04	.195+04
	57.4	178.
	31.8	77.3
	.737	.456
	10.2	< 8.04
NICKEL SELENIUM TELLURIUM THALLIUM TIN	34.3	< 142.
	< 33.2	< 46.9
	1.11	< 5.53
	34.3	< 374.
	8.36	< 218.
TITANIUM URANIUM VANADIUM ZINC ZIRCONIUM	1.22	580.
	.000	.000
	6.10	< 17.2
	62.6	< 35.3
	.000	.000
ANIONS CHLORIDE FLUORIDE CYANIDE NITRATE SULFATE AMMONIUM	* .000	* .000
	* .000	* .000
	* .000	* .000
	* .000	* .000
	* .000	* .000

APPENDIX E
ORGANIC ANALYSIS DATA

TABLE E-1. IR RESULTS OF TOTAL EXTRACTS

Baseline

Bottom Ash

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3100-3600	m	hydroxyl	
2960, 2930, 2860	s	aliphatic C-H	
1745	s	carbonyl	broad
1470-1450,			broad
1380-1370	m	aliphatic bending	

Weak spectro-peaks all broad-possible carboxylic acid

Low NO_x

Bottom Ash

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2800-3650	s	hydroxyl	
2920, 2860	m	aliphatic CH	
1710	m	carbonyl	very broad
1170	s	C-O	possible ester or ether

TABLE E-1. Continued

Boiler Outlet -- 10 m + 3 m Extract

Baseline

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2930, 2860	S	aliphatic CH	
1730	S	carbonyl	

Low NO_x

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2940, 2860	S	aliphatic CH	
1740	m	carbonyl	
1470	m	aliphatic	broad
1310-1380	m	bending	
1290-1260		unassigned	broad

Boiler Outlet -- XAD-2 Resin

Baseline

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3650-2800	m	hydroxyl	broad
2960, 2920, 2860	S	aliphatic CH	
1725	S	carbonyl	
1460, 1380	m	methyl/aliphatic bending	
1600	W	aromatic double bond	
1300-1000	m	unassigned	broad jumble

Carboxylic acid -- identical to Low NO_xLow NO_x

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3650-2800	m	hydroxyl	broad
2960, 2920, 2860	S	aliphatic CH	
1725	S	carbonyl	
1460, 1380	m	methyl/aliphatic bending	
1300-1000	m	unassigned	broad jumble

TABLE E-1. Continued

Boiler Outlet -- XAO-2 Extract -- Gravometric Fraction

Baseline

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3600-2700	s	hydroxyl	broad
2960, 2930, 2880	s		
2860		aliphatic CH	
1720	s	carbonyl	broad
1610	w	aromatic C=C	
1460, 1380	m	methyl aliphatic bending	
1300-1000	m	principally C-O bonds with at least 2 unknown bonds	

Low NO_x

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3600-2800	w	hydroxyl	broad
2960, 2930, 2880			
2860	s	aliphatic CH	
1740	m	carbonyl	
1470, 1380	m	methyl/aliphatic bending	
1300-1000	m	unassigned	broad jumble

Weak spectrum -- basically the same as Baseline result

TABLE E-1. Continued

Mechanical Hopper Ash

Baseline

No peaks of significant intensity

Low NO_x

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2970, 2940, 2860	S	aliphatic C-H	
1730	S	carbonyl	
1120	S	C-O linkage (ether, ester)	broad

Extremely weak spectrum

TABLE E-1. Continued

ESP Ash

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2930, 2880, 2860,	m	aliphatic CH	
1730-40	m	carbonyl	
1375	s	unassigned	very large
1290	m	unassigned	
1205	m	unassigned	
1125	m	unassigned	
1080	m	unassigned	

1375 cm⁻¹ peak present in blank at a lesser intensity

ESP Hopper Ash

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2970, 2930			
2860	s	aliphatic CH	
1730	s	carbonyl	
1370	vs	unassigned	

Extremely weak spectrum -- Peak at 1370 cm⁻¹ thought to be organic

TABLE E-1. Concluded

ESP Outlet -- XAD-2 Extract

Baseline

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3600-2700	s	hydroxyl	broad
2960, 2920, 2870			
2860	s	aliphatic CH	
1720	s	carbonyl	
1600	w	aromatic C=C	
1450, 1380			
1370	m	methyl/aliphatic bending	
1330-1000	s	contains C-O stretch	broad junkie
730-600	w	unassigned	

Carboxylic acid, contains some aromatics

Low NO_x

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3600-2700	m	hydroxyl	broad
2960, 2920, 2860	s	aliphatic CH	
1725	s	carbonyl	
1635	w	amide carbonyl	
1550, 1380	m	possible nitro group	
1460	s	phenol band - or both	
1460, 1380	s, m	methyl/aliphatic bending	
1300, 1000	m	unassigned	broad junkie

Hydroxyl/aliphatic CH ratio considerably less than Baseline -- possible amide and aromatic

TABLE E-2. IR RESULTS OF LC FRACTIONS

Boiler Outlet -- XAD-2 Resin Extract

Baseline LC-1

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2920, 2850	S	aliphatic CH	

Very weak spectrum

Low NO_x LC-1

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2920, 2850	S	aliphatic CH	
1730	m	carbonyl	
1460, 1380	m	methyl/aliphatic bending	

Very weak spectrum -- presence of carbonyl indicates
LC fractionation is off

Baseline LC-2

No peak other than present in blanks

Low NO_x LC-2

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2920, 2850	S	aliphatic CH	

Extremely weak spectrum -- vague C-H discernable

TABLE E-2. Continued

Baseline LC-3

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2930, 2850	s	aliphatic CH	

Low NO_x LC-3

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2920, 2850	s	aliphatic CH	
1181	s	unassigned	
1110	s	unassigned	

Baseline LC-4

No peak other than present in blanks

Low NO_x LC-4

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2930, 2860	aliphatic s	aliphatic CH	
1725	s	carbonyl	

TABLE E-2. Continued

Baseline LC-5

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
2960, 2930, 2860	s	aliphatic CH	
1720	s	carbonyl	

Very weak spectrum

Low NO_x LC-5

No peaks other than present in blank

Baseline LC-6

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3600-3200	w	hydroxyl	broad
2960, 2920, 2860			
2860	s	aliphatic CH	
1735	s	carbonyl	
1460, 1375	m	methyl / aliphatic bending	
1300-1150	m	5 bands, 4 unassigned	
~~1120~~	~~g~~	1 C-O	
1120	w	unassigned	
1080	w	unassigned	

Good spectrum; appears that acid or alcohol is minor constituent -- different from LC-6 for Low NO_x

TABLE E-2. Concluded

Low NO_x LC-6

Wave Number (cm ⁻¹)	Intensity	Assignment	Comments
3600-3100	w	hydroxyl	broad
2960, 2920, 2880,			
2860	m	aliphatic CH	
1735	s	carbonyl	
1460(h), 1430			
1370	m	methyl/aliphatic bending	
1240	s	C-O	
1280 sh	w	unassigned	
1125	w	"	
1080	w	"	
1030	w	"	

Either aliphatic ketone with acid as minor constituent
or acid with very strong hydrogen bonding

Baseline LC-7

No peaks other than present in blank

Low NO_x LC-7

No peaks other than present in blank